TRANSACTIONS

OF THE

KANSAS ACADEMY OF SCIENCE

VOLUME 37

F. C. GATES, *Editor*
W. J. BAUMGARTNER, *Managing Editor*

SIXTY-SIXTH ANNUAL MEETING, APRIL 26-28, 1934

Municipal University of Wichita and Wichita High School East, Wichita, Kansas

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Manhattan, Kansas, U. S. A.

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CONSTITUTION AND BY-LAWS

CONSTITUTION *

SECTION 1. This association shall be called the Kansas Academy of Science.

SEC. 2. The objects of this Academy shall be to increase and diffuse knowledge in various departments of science.

SEC. 3. The membership of this Academy shall consist of three classes: annual, life and honorary.

(1) Annual members may be elected at any time by the committee on membership, which shall consist of the secretary and other members appointed, annually, by the president. Annual members shall pay annual dues of one dollar, but the secretary and treasurer shall be exempt from the payment of dues during the years of their service.

(2) Any person who shall have paid thirty dollars in annual dues, or equivalent due to legal exemption, or in one sum, or in any combination, may be elected to life membership, free of assessment, by a two-thirds vote of the members present at an annual meeting.

(3) Honorary members may be elected because of special prominence in science upon written recommendation of two members of the Academy, by a two-thirds vote of the members present. Honorary members pay no dues.

SEC. 4. The officers of this Academy shall be chosen by ballot at the annual meeting, and shall consist of a president, two vice presidents, a secretary and a treasurer, who shall perform the duties usually pertaining to their respective offices. The president, the secretary and the treasurer shall constitute the executive committee. The secretary shall be in charge of all the books, collections and material property belonging to the Academy.

SEC. 5. Unless otherwise directed by the Academy, the annual meeting shall be held at such time and place as the executive committee shall designate. Other meetings may be called at the discretion of the executive committee.

SEC. 6. This constitution may be altered or amended at any annual meeting by a vote of three-fourths of attending members of at least one year's standing. No question of amendment shall be decided on the day of its presentation.

SEC. 7. This Academy shall have an executive council consisting of the president, the secretary, the treasurer, the vice presidents, the chairmen of the sections and the retiring president, and other members to be nominated by the nominating committee and elected as the other officers. This council shall have general oversight of the Academy not otherwise given by this Constitution to officers or committees.

* As modified by amendments.

BY-LAWS

I. At the beginning of each annual session there shall be held a brief business meeting for announcements and appointment of committees. For the main business meeting, held later in the session, the following order is suggested:

1. Reports of officers.
2. Reports of standing committees.
3. Unfinished business.
4. New business.
5. Reports of special committees.
6. Election of officers.
7. Election of life and honorary members.

II. The president shall deliver a public address on the evening of one of the days of the meeting, at the expiration of his term of office.

III. No meeting shall be held without a notice of the same having been published in the papers of the state at least thirty days previous.

IV. No bill against the Academy shall be paid by the treasurer without an order signed by the president and secretary.

V. Names of members more than one year in arrears in dues shall be dropped from the membership list.

VI. The secretary shall have charge of the distribution, sale and exchange of the published Transactions of the Academy, under such restrictions as may be imposed by the executive committee.

VII. Ten per cent of the active membership shall constitute a quorum for the transaction of business. Section meetings may not be scheduled or held at the time a business meeting is called by the president at a general session or announced on the program.

VIII. The time allotted to the presentation of a single paper shall not exceed fifteen minutes.

IX. No paper shall be entitled to a place on the program unless the manuscript, or an abstract of the same, shall have been previously delivered to the secretary.

X. Section programs may be arranged by the secretary with the advice of the section chairman. The subdivision or combination of existing sections shall be dependent upon the number of papers to be presented. Such changes shall be made by the secretary in accordance with the policies of the Academy and after receiving the advice of the chairmen of the sections concerned.

XI. Section chairmen for the ensuing year shall be elected annually at the close of the section meetings.

XII. Section programs shall be limited to Friday afternoon of the annual session, but may be continued Saturday afternoon if desired by the section chairman. Exceptions to this must receive the approval of the executive committee.

PAST OFFICERS OF THE ACADEMY

Year.	President.	First Vice President.	Second Vice President.	Secretary.	Treasurer.
1869	B. F. Mudge	J. S. Whitman		J. D. Parker	F. H. Snow
1870	B. F. Mudge	J. S. Whitman		J. D. Parker	F. H. Snow
1871	John Fraser	B. F. Mudge		J. D. Parker	F. H. Snow
1872	John Fraser	B. F. Mudge	R. J. Brown	J. D. Parker	F. H. Snow
1873	John Fraser	B. F. Mudge	R. J. Brown	J. D. Parker	F. H. Snow
1874	F. H. Snow	J. A. Banfield	J. D. Parker	John Wherrell	R. J. Brown
1875	F. H. Snow	B. F. Mudge	J. D. Parker	John Wherrell	R. J. Brown
1876	F. H. Snow	B. F. Mudge	J. H. Carruth	Joseph Savage	R. J. Brown
1877	F. H. Snow	B. F. Mudge	J. H. Carruth	Joseph Savage	R. J. Brown
1878	F. H. Snow	B. F. Mudge	J. H. Carruth	E. A. Popenoe	R. J. Brown
1879	B. F. Mudge	J. H. Carruth	Joseph Savage	E. A. Popenoe	R. J. Brown
1880	B. F. Mudge	J. H. Carruth	Joseph Savage	E. A. Popenoe	R. J. Brown
1881	J. T. Lovewell	J. H. Carruth	Joseph Savage	E. A. Popenoe	R. J. Brown
1882	J. T. Lovewell	J. H. Carruth	Joseph Savage	E. A. Popenoe	R. J. Brown
1883	A. H. Thompson	J. R. Mead	G. E. Patrick	E. A. Popenoe	R. J. Brown
1884	R. J. Brown	F. H. Snow	Joseph Savage	E. A. Popenoe	A. H. Thompson
1885	R. J. Brown	E. L. Nichols	G. H. Failyer	E. A. Popenoe	A. H. Thompson
1886	E. L. Nichols	J. D. Parker	N. S. Goss	E. A. Popenoe	I. D. Graham
1887	J. D. Parker	J. R. Mead	E. H. S. Bailey	E. A. Popenoe	I. D. Graham
1888	J. R. Mead	E. H. S. Bailey	T. H. Dinsmore, Jr.	E. A. Popenoe	I. D. Graham
1889	T. H. Dinsmore, Jr.	E. H. S. Bailey	G. H. Failyer	E. A. Popenoe	I. D. Graham
1890	G. H. Failyer	D. S. Kelly	F. W. Cragin	E. H. S. Bailey	I. D. Graham
1891	Robert Hay	F. W. Cragin	O. C. Charlton	E. H. S. Bailey	F. O. Marvin
1892	E. A. Popenoe	F. O. Marvin	Mrs. N. S. Kedzie	E. H. S. Bailey	D. S. Kelly
1893	E. H. S. Bailey	J. T. Willard	E. B. Kneer	A. M. Collete	D. S. Kelly
1894	L. E. Sayre	I. D. Graham	J. L. Howitt	E. B. Kneer	D. S. Kelly
1895	Warren Knaus	I. D. Graham	S. W. Williston	E. B. Kneer	D. S. Kelly
1896	D. S. Kelly	S. W. Williston	D. E. Lantz	E. B. Kneer	L. E. Sayre
1897	S. W. Williston	D. E. Lantz	A. S. Hitchcock	E. B. Kneer	J. W. Beede
1898	D. E. Lantz	C. S. Parmenter	L. C. Wooster	E. B. Kneer	J. W. Beede
1899	E. B. Kneer	A. S. Hitchcock	J. R. Mead	D. E. Lantz	J. W. Beede
1900	A. S. Hitchcock	E. Miller	J. C. Cooper	D. E. Lantz	J. W. Beede
1901	E. Miller	J. C. Cooper	L. C. Wooster	D. E. Lantz	E. C. Franklin
1902	J. T. Willard	Edward Bartow	J. A. Yates	G. P. Grimsley	E. C. Franklin
1903	J. C. Cooper	Edward Bartow	J. A. Yates	G. P. Grimsley	Alva J. Smith
1904	Edward Bartow	L. C. Wooster	B. F. Eyer	G. P. Grimsley	Alva J. Smith
1905	L. C. Wooster	F. W. Bushong	W. A. Harshbarger	J. T. Lovewell	Alva J. Smith
1906	F. O. Marvin	B. F. Eyer	J. E. Welin	J. T. Lovewell	Alva J. Smith
1907	J. A. Yates	E. Haworth	F. B. Dains	J. T. Lovewell	Alva J. Smith
1908	E. Haworth	F. B. Dains	J. M. McWharf	J. T. Lovewell	Alva J. Smith
1909	F. B. Dains	J. M. McWharf	Alva J. Smith	J. T. Lovewell	F. W. Bushong
1910	F. B. Dains	J. M. McWharf	Alva J. Smith	J. T. Lovewell	F. W. Bushong
1911	J. M. McWharf	Alva J. Smith	J. E. Welin	J. T. Lovewell	F. W. Bushong
1912	F. W. Bushong	Alva J. Smith	J. E. Welin	J. T. Lovewell	L. D. Havenhill
1913	Alva J. Smith	W. A. Harshbarger	J. A. G. Shirk	J. T. Lovewell	L. D. Havenhill
1914	W. A. Harshbarger	J. A. G. Shirk	J. E. Todd	J. T. Lovewell	L. D. Havenhill
1915-1916	J. A. G. Shirk	J. E. Todd	F. U. G. Agrelius	J. T. Lovewell	L. D. Havenhill
1916-1917	J. E. Todd	F. U. G. Agrelius	L. D. Havenhill	W. W. Swingle	W. A. Harshbarger
1917-1918	F. U. G. Agrelius	L. D. Havenhill	B. M. Allen	W. W. Swingle H. W. Swingle Guy West Wilson	W. A. Harshbarger
1918-1919	L. D. Havenhill	R. K. Nabours	B. M. Allen	Guy West Wilson	F. C. Bruchmiller
1919-1920	R K. Nabours	B. M. Allen	O. P. Dellinger	E. A. White	L. D. Havenhill
1920-1921	O. P. Dellinger	Roy Rankin	W. P. Hays	E. A. White	L. D. Havenhill
1921-1922	Roy Rankin	R. K. Nabours	W. R. B. Robertson	E. A. White	L. D. Havenhill
1922-1923	R. K. Nabours	H. P. Cady	H. H. Nininger	E. A. White	L. D. Havenhill
1923-1924	H. P. Cady	H. H. Nininger	J. E. Ackert	E. A. White	L. D. Havenhill
1924-1925	H. H. Nininger	J. E. Ackert	F. U. G. Agrelius	E. A. White	L. D. Havenhill
1925-1926	J. E. Ackert	H. M. Elsey	W. M. Goldsmith	E. A. White	L. D. Havenhill
1926-1927	H. J. Harnly	Mary T. Harman	L. D. Wooster	E. A. White	L. D. Havenhill
1927-1928	Mary T. Harman	L. D. Wooster	W. B. Wilson	E. A. White	L. D. Havenhill
1928-1929	L. D. Wooster	W. B. Wilson	Hazel E. Branch	G. E. Johnson	L. D. Havenhill
1929-1930	W. B. Wilson	Hazel E. Branch	W. M. Goldsmith	G. E. Johnson	R. Q. Brewster
1930-1931	Hazel E. Branch	R. C. Smith	W. H. Matthews	G. E. Johnson	R. Q. Brewster
1931-1932	R. C. Smith	W. J. Baumgartner	J. W. Hershey	G. E. Johnson	R. Q. Brewster
1932-1933	Robert Taft	J. W. Hershey	W. H. Matthews	G. E. Johnson	H. A. Zinsser
1933-1934	J. W. Hershey	W. H. Matthews	E. A. Marten	G. E. Johnson	H. A. Zinsser
1934-1935	W. H. Matthews	E. A. Marten	W. J. Baumgartner	G. E. Johnson	H. A. Zinszer

NOTE.—Previous to 1931-'32 the secretary was also editor. Since 1931-'32 F. C. Gates has been editor.

MEMBERSHIP OF THE ACADEMY

May 21, 1934

ABBREVIATIONS: The following abbreviations for institutions have been used:

U. of K.: University of Kansas.
K. S. C.: Kansas State College of Agriculture and Applied Science.
K. S. T. C.: Kansas State Teachers College.
F. H. K. S. C.: Fort Hays Kansas State College.
H. S.: High School.
Jr. H. S.: Junior High School.
Jr. Col.: Junior College.

Other abbreviations follow those used in the Summarized Proceedings of the American Association for the Advancement of Science.

The year given indicates the time of election to membership.

HONORARY MEMBERS

Barber, Marshall A., Ph. D., 1904, Internat. Health Div., Rockefeller Found., 61 Broadway, New York, N. Y.
Cockerell, T. D. A., D. Sc., 1908, prof. zoölogy, Univ. Colorado, Boulder, Colo.
Franklin, Edward Curtis, Ph. D., 1884, prof. chemistry, Leland Stanford, Jr., Univ., Cal.
Grimsley, G. P., Ph. D., 1896, geological eng., B. & O. R. R., 4405 Underwood Road (Guilford), Baltimore, Md.
Hitchcock, A. S., Sc. D., 1892, principal botanist, U. S. Dept. Agric., Washington, D. C.
Kellogg, Vernon L., LL. D., Sc. D., 1920, permanent secretary, National Research Council, Washington, D. C. (2305 Bancroft Place.)
McClung, C. E., Ph. D., 1903, dir. zoölogy lab., Univ. Pennsylvania, Philadelphia, Pa.
McCollum, E. V., Ph. D., Sc. D., 1902, prof. biochemistry, Johns Hopkins Univ., Baltimore, Md.
Nichols, Edward L., Ph. D., Sc. D., 1885 (honorary member 1897), prof. physics (emeritus), Cornell Univ., Ithaca, N. Y.
Riggs, Elmer S., M. A., 1896, assoc. curator paleontology, Field Mus. Nat. Hist., Chicago, Ill.
Wagner, George, M. A., 1897 (honorary member 1904), prof. zoölogy, Univ. Wisconsin, Madison, Wis.

LIFE MEMBERS

Agrelius, Frank U. G., M. A., 1905, assoc. prof. biol., K. S. T. C., Emporia, Kan.
Allen, Herman Camp., Ph. D., 1904, prof. chemistry, U. of K., Lawrence, Kan.
Bartholomew, Elam, Sc. D., 1896, 415 W. Sixth street, Hays, Kan.
Bartow, Edward, Ph. D., Sc. D., 1897, prof. and head Dept. Chem. and Chem. Eng., State Univ. Iowa, Iowa City, Iowa.
Baumgartner, William J., Ph. D., 1904, assoc. prof. zoölogy, U. of K., Lawrence, Kan.
Beede, Joshua W., Ph. D., 1894, prof. geology and paleontology, Indiana Univ., Bloomington, Ind.
Berry, Sister M. Sebastion, A. B., 1911, Supt. Schools, St. Paul, Kan.
Bushnell, Leland D., Ph. D., 1908, prof. and head Bacteriology Dept., K. S. C., Manhattan, Kan.
Bushong, F. W., Sc. D., 1896, 2636 Fifth street, Port Arthur, Tex.
Cady, Hamilton P., Ph D., 1904, prof. chemistry, U. of K., Lawrence, Kan.
Copley, Rev. John T., 1908, Olathe, Kan.
Cragin, F. W., Ph. D., 1880, 912 Miguel street, Colorado Springs, Colo.
Cook, W. A., M. S., 1907, real estate business, 1414 Highland street, Salina, Kan.
Dains, Frank Burnett, Ph. D., 1902, prof. chemistry, U. of K., Lawrence, Kan.
Deere, Emil O., M. S., 1905, dean and prof. biology, Bethany Col., Lindsborg, Kan.
Dellinger, Orris P., Ph. D., 1909, prof. biology, K. S. T. C., Pittsburg, Kan.

Dunlevy, R. B., M. A., 1896, Southwestern Col., Winfield, Kan.
Eby, J. Whit, B. S., 1903, banker, Howard, Kan.
Failyer, George H., M. S., 1879, retired, R. R. 4, Manhattan, Kan.
Faragher, Warren F., Ph. D., 1927, asst. chief, Research Dept., Vacuum Oil Co., Inc., Paulsboro, N. J.
Garrett, A. O., M. A., 1901, head Dept. Biology, East High School, Salt Lake City, Utah.
Graham, I. D., M. S., 1879, State Board of Agric., Topeka, Kan.
Harman, Mary T., Ph. D., 1912, prof. zoölogy, K. S. C., Manhattan, Kan.
Harnly, Henry J., Ph. D., 1893, prof. biology, McPherson Col., McPherson, Kan.
Harshbarger, William A., Sc. D., 1903, prof. mathematics, Washburn Col., Topeka, Kan.
Havenhill, L. D., Ph. C., 1904, dean School of Pharmacy, U. of K., Lawrence, Kan.
Haworth, Erasmus, Ph. D., 1882, U. of K., Lawrence, Kan.
King, H. H., Ph. D., 1909, prof. and head Dept. Chemistry, K. S. C., Manhattan, Kan.
Knaus, Warren M., D. Sc., 1882, entomologist, editor *Democrat Opinion*, McPherson, Kan.
McWharf, J. M., M. D., 1902, 715 Princeton street, Ottawa, Kan.
Meeker, Grace R., 1899, 709 S. Mulberry, Ottawa, Kan.
Menninger, C. F., M. D., 1903, 3617 W. Sixth avenue, Topeka, Kan.
Nabours, Robert K., Ph. D., 1910, prof. and head Zoölogy Dept., K. S. C., Manhattan, Kan.
Nissen, A. M., A. B., 1888, farmer, Wetmore, Kan.
Peace, Larry M., 1904, 512 West Ninth street, Lawrence, Kan.
Reagan, Albert B., Ph. D., 1904, Indian Field Service, Ouray, Utah.
Robertson, W. R. B., Ph. D., 1905, Anat. Dept., Univ. Iowa, Iowa City, Iowa.
Schaffner, John H., M. S., 1903, research and prof. botany, Ohio State Univ., Columbus, Ohio.
Scheffer, Theodore, M. A., 1903, assoc. biologist, U. S. Biological Survey, Puyallup, Wash.
Shirk, J. A. G., 1904, prof. mathematics, K. S. T. C., Pittsburg, Kan.
Smith, Alva J., 1892, consulting eng., 810 Boylston street, San Diego, Cal.
Smyth, E. Graywood, 1901, entomologist, Cia. Agricola Carabayllo, Hacienda Cartavio, Trujillo, Peru.
Smyth, Lumina C. R., Ph. D., 1902, 16802 Dartmouth, Cleveland, Ohio.
Sterling, Charles M., A. B., 1904, assoc. prof. botany and pharmacognosy, U. of K., Lawrence, Kan.
Sternberg, Charles H., M. A., 1896, 4046 Arizona street, San Diego, Cal.
Stevens, Wm. C., 1890, head Botany Dept., U. of K., Lawrence, Kan.
Welin, John Eric, D. Sc., 1889, prof. chemistry, Bethany Col., Lindsborg, Kan.
White, E. A., M. A., 1904, prof. chemistry, U. of K., Lawrence, Kan.
Willard, Julius T., D. Sc., 1883, vice president K. S. C., Manhattan, Kan.
Wilson, William B., Sc. D., 1903, head Biology Dept., Ottawa Univ., Ottawa, Kan.
Wooster, Lyman C., Ph. D., 1889, prof. biology and geology, K. S. T. C., Emporia, Kan.
Yates, J. A., Ph. D., 1898, prof. chemical and physical science, K. S. T. C., Pittsburg, Kan. (Deceased.)

ANNUAL MEMBERS

Members who paid their 1934 dues before May 21, 1934, are indicated by an asterisk (*). The year given is that of election to membership. If two years are given the second signifies reëlection.

*Ackert, James E., Ph. D., 1919, prof. zoölogy, parasitologist, dean Graduate Div., K. S. C., Manhattan, Kan.
*Aicher, L. C., B. S., 1930, supt. Fort Hays Branch, K. S. A. Expt. Sta., Hays, Kan.
*Albright, Penrose S., M. S., 1926, asst. prof. physics and chem., Southwestern Col., Winfield, Kan.
*Aller, Alvin R., M. S., 1932, 607 E. 16th street, Hutchinson, Kan.
*Alm, O. W., Ph. D., 1931, assoc. prof. psychology, K. S. C., Manhattan, Kan.
*Alsop, M. L., M. S., 1932 teacher, H. S., Wamego, Kan.
*Aubel, C. E., M. S., 1933, assoc. prof. animal husbandry, K. S. C., Manhattan, Kan.
*Ayres, H. D., Ph. D., 1928. head Dept. Physics, Univ. Wichita, Wichita, Kan.
*Babcock, Rodney W., Ph. D., 1931, dean, Div. Gen. Sci., K. S. C., Manhattan, Kan.
*Baden, Martin W., Sc. D., 1929, Box 520, Winfield, Kan.
*Baker, Burton L., A. B., 1934, grad. res. asst. zoölogy, K. S. C., Manhattan, Kan.
*Bardo, Carol, A. B., 1933, laboratory technician, 120 E. Washington avenue, Arkansas City, Kan.

*Barham, Harold N., Ph. D., 1931, assoc. prof. chemistry, K. S. C., Manhattan, Kan.
*Barnett, R. J., M. S., 1922, prof. horticulture, K. S. C., Manhattan, Kan.
*Barnhart, Carl, B. S., 1932, instr. H. S. East, Wichita, Kan.
*Barton, A. W., Ph. D., 1928, prof. botany, F. H. K. S. C., Hays, Kan.
*Bates, James, M. A., 1933, asst. instr. botany, U. of K., Lawrence, Kan.
*Baxter, Walter, 1934, student, botany, U. of K., Lawrence, Kan.
*Beach, Edith, M. A., 1931, 812 Illinois street, Lawrence, Kan.
Beadle, B., 1933, student, chemistry, K. S. C., Manhattan, Kan.
Benne, E. J., M. S., 1933, instr. chemistry, K. S. C., Manhattan, Kan.
*Benne, Kenneth, B. S., 1933, science teacher, H. S., Concordia, Kan.
*Bennett, Dewey, M. A., 1928, instr. biology and chemistry, Junior Col., Garden City, Kan.
Bentley, Jay, B. S., 1933, asst. pasture improvement, K. S. C., Manhattan, Kan.
*Black, Paul E., 1933, R. R. 1, Olathe, Kan.
*Boughton, L. L., M. S., 1929, asst. prof. pharmacy, U. of K., Lawrence, Kan.
*Bowman, J. L., M. S., 1928, McPherson Col., McPherson, Kan.
Bradley, C. R., M. S., 1933, Mayetta, Kan.
*Branch, Hazel E., Ph. D., 1924, prof. zoölogy, Univ. Wichita, Wichita, Kan.
*Brennan, L. A., A. B., 1933, teacher, biology, St. Joseph's Col., Hays, Kan.
*Breukelman, John, Ph. D., 1930, prof. biology, K. S. T. C., Emporia, Kan.
*Brewster, Ray Q., Ph. D., 1919, prof. chemistry, U. of K., Lawrence, Kan.
Brill, Alice K., B. S., 1933, res. asst., food econ. and nutrition, K. S. C., Manhattan, Kan.
*Brooks, Charles H., M. S., 1929, Extension Div., F. H. K. S. C., Hays, Kan.
*Brooks, Frank M., 1934, student, Univ. Wichita, Wichita, Kan.
*Brown, Harold P., Ph. D., 1934, prof. chemistry, Univ. Kansas City, Kansas City, Mo.
*Brown, J. F., Ph. D., 1933, asst. prof. psychology, U. of K., Lawrence, Kan.
Brown, Maud A., 1920, 1931, Crescent Road, Lawrence, Kan.
*Brubaker, H. W., Ph. D., 1929, prof. chemistry, K. S. C., Manhattan, Kan.
Bryson, Harry R., M. S., 1933, asst. prof. entomology, K. S. C., Manhattan, Kan.
Burget, Irma A., A. B., 1933, asst. botany, U. of K., Lawrence, Kan.
*Burt, Charles E., Ph. D., 1932, prof. biology, Southwestern Col., Winfield, Kan.
*Caldwell, J. Marvin, A. B., 1934, grad. student, U. of K., Lawrence, Kan.
Caldwell, M. J., B. S., 1933, grad. asst. chem., K. S. C., Manhattan, Kan.
*Call, L. E., M. S., 1922, dean, Div. Agric., dir. Agric. Exp. Sta., K. S. C., Manhattan, Kan.
Campbell, Marion I., M. S., 1929, Topeka State Hospital, Topeka, Kan.
*Carlson, Hjalmar E., M. D., 1932, asst. surgery, U. of K. Med. Sch., 3944 Rainbow Blvd., Kansas City, Kan.
*Carpenter, A. C., 1929, president, Lesh Oil Co., Ottawa, Kan.
Casey, R. B., M. S., 1933, grad. student, zoölogy, K. S. C., Manhattan, Kan.
Caulfield, Wilber J., M. S., 1933, asst. prof. dairy husbandry, K. S. C., Manhattan, Kan.
Cave, H. W., M. S., 1933, prof. dairy husbandry, K. S. C., Manhattan, Kan.
*Chapin, Ernest K., M. S., 1934, assoc. prof. physics, K. S. C., Manhattan, Kan.
*Chance, Sylvester, A. B., 1932, physiology, Wichita H. S. East, Wichita, Kan.
Chidester, Leona, M. A., 1933, psychologist, Menninger Clinic, Topeka, Kan.
Chitwood, Ida, M. S., 1933, Meriden, Kan.
*Choguill, Harold S., A. M., 1934, instr. physics, Jr. Col., Garden City, Kan.
Clopton, Clair D., 1933, student chemistry, K. S. T. C., Emporia, Kan.
*Cobden, Edith, M. S., 1934, 553 N. Fountain, Wichita, Kan.
*Coco, Russell M., M. S., 1932, instr. H. S., Bordelonville, La.
Conrad, R. M., B. S., 1933, student chemistry, K. S. C., Manhattan, Kan.
*Cowan, Edwina, Ph. D., 1929, dir. Wichita Child Res. Lab., Friends Univ., Wichita, Kan.
*Crow, H. Ernest, Ph. D., 1926, prof. biology, Friends Univ., Wichita, Kan.
Cruise, Lawrence L., M. S., 1930, physics and mathematics, Jr. Col., Rochester, Minn.
Cypert, Eugene, Jr., M. S., 1932, 105 Greening street, Camden, Ark.
*Daniels, Chas. M., A. B., 1934, Univ. Wichita, Wichita, Kan.
*Davidson, Arthur W., Ph. D., 1927, assoc. prof. chemistry, U. of K., Lawrence, Kan.
*Davis, Rex H. A., A. M., 1931, H. S., Atchison, Kan.
*Dean, George A., M. S., 1903, 1912, head Dept. Entomology, K. S. C., Manhattan, Kan.
Dean, L. Marjorie, M. S., 1933, 1725 Poynts, Manhattan, Kan.
*Dellett, Fred V., B. S., 1931, Pawnee Rock, Kan.
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Wilmoth, James H., M. S., 1933, grad. student, zoölogy, K. S. C., Manhattan, Kan.
*Wilson, Jack Turner, A. B., 1933, instr. chemistry, Emporia Col., Emporia, Kan.
Wimmer, Edward J., Ph. D., 1928, asst. prof. zoölogy, K. S. C., Manhattan, Kan.
Winters, Estelle, M. S., 1933, Onaga, Kan.
Wismer, C. A., B. S., 1933, grad. asst. botany, K. S. C., Manhattan, Kan.
*Wismer, Nettie M., M. S., 1932, science teacher, Jr. H. S., Lawrence, Kan.
*Wood, Robert E., M. S., 1930, chemistry, H. S., Lawrence, Kan.
*Woodard, Parke, M. D., 1930, asst. prof. physiology, U. of K., Lawrence, Kan.
*Wooster, L. D., Ph. M., 1924, prof. zoölogy, F. H. K. S. C., Hays, Kan.
*Wyman, Fred Jr., 1934, student, Col. Emporia, Emporia, Kan.
*Yoder, J. J., LL. D., 1926, prof. sociology, McPherson Col., McPherson, Kan.
*Zinsser, Harvey A., Ph. D., 1930, prof. physics and astronomy, F. H. K. S. C., Hays, Kan.
*Zinsser, Richard H., B. S., (Eng.), 1931, 422 W. 12th street, Hays, Kan.

SIXTY-SIXTH ANNUAL MEETING

KANSAS ACADEMY OF SCIENCE

Municipal University of Wichita and Wichita High School East, Wichita, Kan., April 26-28, 1934

OFFICERS OF THE ACADEMY

J. WILLARD HERSHEY, McPherson....................................President
WM. H. MATTHEWS, Pittsburg ....First Vice President
E. A. MARTEN, Wichita..................................Second Vice President
GEORGE E. JOHNSON, Manhattan...................................Secretary
HARVEY A. ZINSZER, Hays...Treasurer

Chairmen of Sections

H. E. CROW, Biology
P. A. READIO, Entomology
J. B. STROUD, Psychology
W. W. FLOYD, Chemistry
G. W. MAXWELL, Physics
HAZEL E. BRANCH, Junior Academy
ELSA HORN STILES, Vice Chairman, Biology
WM. H. MATTHEWS, Chairman *pro. tem.*, Physics

Additional Members of the Executive Council

ROBERT TAFT, Lawrence
L. ONCLEY, Winfield
F. U. G. AGRELIUS, Emporia

PROGRAM

THURSDAY, APRIL 26

8:15 p. m. "Kansas Weather and Its Effects on Crops." S. D. Flora, Meteorologist of the U. S. Weather Bureau at Topeka. Auditorium, University of Wichita.

FRIDAY, APRIL 27

9:00 a. m. General papers, Auditorium, University of Wichita.
11:30 a. m. "The Kansas Soil Erosion Demonstration." Dr. F. L. Duley, U. S. Department Interior, Mankato. Auditorium.
1:00 p. m. Exhibits and demonstrations, Science Hall, Room 111 and Room 116.
1:00 p. m. Junior Academy of Science, Science Hall, Room 102.
1:30 p. m. Section Programs:
a. Biology, Science Hall, Room 207.
b. Chemistry, Science Hall, Room 306.
c. Physics, Science Hall, Room 204.
d. Psychology, Administration Building, Room 427.
5:45 p. m. Banquet at Wichita High School East.
Toastmaster, Lloyd McKinley, Wichita.
Address of Welcome: Wm. M. Jardine, President of University of Wichita.
Response: J. B. Stroud, Emporia.
Presidential Address: "The Historical Development of the Relationship oi Gasses to Animal Life." J. Willard Hershey, McPherson College.
8:15 p. m. Address: "A Boat Trip Through the Grand Canyon of the Colorado," a lecture illustrated with colored lantern slides and motion pictures. Dr. Raymond C. Moore, state geologist, University of Kansas, Wichita High School East, Auditorium.

SATURDAY, APRIL 28

8:15 a. m. General papers and business. University of Wichita, Auditorium.
11:00 a. m. Entomology papers, Science Hall, Room 119.
12:00 m. Meeting of the new Executive Council.
1:30 p. m. Entomology papers, Science Hall, Room 119.

PAPERS SUBMITTED FOR THE SIXTY-SIXTH ANNUAL MEETING

GENERAL PAPERS

Friday, April 27, 9 a. m., Auditorium, University of Wichita

1. Some Physiographic and Stratigraphic Observations in the Flint Hills. J. M. Jewett, U. of W.
2. A Flint Hills Stratigraphic Section. F. M. Brooks, U. of W.
3. Additions to the List of Mammals from the Equus Beds. H. J. Harnly, McPherson Col.
4. The Contribution of Secondary School Chemistry Courses to Proficiency in General Inorganic and Qualitative Analysis Courses in the University of Kansas. W. W. Floyd, Ottawa Univ.
5. Anterior Pituitary Experiments on Ground Squirrels. G. E. Johnson, K. S. C.
6. Notes on the Results of Feeding Nicotine to Albino Rats. Hazel E. Branch, U. of W.
7. Plant Sap and Juice. III. Hydrogen Ion Concentration and Other Data. A. W. Barton, F. H. K. S. C.
8. Effects of Ultra-violet Light and Ultra Short Waves on Microörganisms. L. J. Gier, K. S. T. C., Pittsburg.
9. Studies on the Effects of Some Alkaloids on Aspergillus. J. C. Bates, U. of K.
10. Additional Studies on Living Tissues. W. J. Baumgartner, U. of K.
11. The Habits and Control of Pharaoh's Ant, a Serious Household Pest in Kansas. R. C. Smith, K. S. C.
12. The Relation Between Size of School by Enrollment and Educational Achievement. H. E. Schrammel, K. S. T. C., Emporia.

PAPERS READ BY TITLE

1. a. Additional Archæological Notes on the Unitah Basin, in Northeastern Utah.
   b. Plants Used by the Hoh and Quileute Indians.
   c. Myths of the Hoh and Quileute Indians. Albert B. Reagan, Ouray, Utah.
2. The Preparation of Some New Azo Derivatives of Guaiacol. C. M. Daniels and W. A. Fletcher, U. of W.
3. Analyses of Fragments from the Tusks of Four Specimens of Extinct Elephants Found in Kansas. H. W. Brubaker, K. S. C.
4. A Newly Found Locality of Glacial Striæ South of the Missouri River. J. M. Jewett, U. of W.
5. Study of the Retinal Pigment of the Embryo Chick. Edith Cobden, U. of W.
6. Greeley Sorghum. J. H. Parker, K. S. C.
7. Grading an "Objective" Examination. H. G. Hodge and T. D. Homan, Univ. Rochester and Ottawa Univ.

BIOLOGY PAPERS

Friday, April 27, 1:30 p. m., Science Hall, Room 207

H. E. Crow, Wichita, Chairman

1. Flagella and Flagella Staining. C. C. McDonald, U. of W.
2. A Method for the Study of Living Cells, and Some Observations on the Structure of Cytoplasm. F. C. Sauer, U. of K.
3. a. A Device for Simultaneous Washing of Cytological or Histological Material.
   b. The Cytoplasmic Compounds of the Male Germ Cells of the Acrididæ With Special Reference to the Golgi-bodies and Terminal Vesicle. V. S. Gentry, U. of K.
4. Some Newer Interpretations of Protozoan Behavior. A. W. McCullough. U. of K.
5. a. Cocao Bean and Elimination: II. Some Personal Experiences.
   b. Preseasonal Vernation; Forced Bud Development. A. W. Barton, F. H. K. S. C.

BOTANY PAPERS

Friday, April 27, about 2:30 p. m., Science Hall, Room 119

Elsa Horn Stiles, Manhattan, Chairman

1. Kansas Botanical Notes, 1933. F. C. Gates, K. S. C.
2. Biology and Structure of *Dianthera americana*. W. C. Stevens, U. of K.
3. Biology and Structure of *Gonolobus lævis*. R. L. Dill, U. of K.
4. Study of Peridermium Gall on Western Yellow Pine. L. J. Gier, K. S. T. C., Pittsburg.
5. A Combination of Vulcanizing and Hydrofluoric Acid Treatment in Preparing Hard Woods for Sectioning. J. C. Bates and Kathryn Taggart, U. of K.
6. Biology and Structure of *Melanthium virginicum*. Kathryn Staley, U. of K.
7. Some Anatomical Features of the Compositæ. M. W. Mayberry, U. of K.
8. Flora of Osborne County, Kansas. S. J. Neher, Portis.
9. Some Mosses Collected in the Vicinity of Lawrence, Kansas. Rufus Thompson, U. of K.
10. On the Tracheal Elements of Some Kansas Shrubs. D. J. Obee, U. of K.
11. Native Flora of Sedgwick County, Kansas. Sister M. Aquinas Stieferman, Sacred Heart Col., Wichita.

ZOÖLOGY PAPERS

Friday, April 27, about 2:30 p. m., Science Hall, Room 207

H. E. Crow, Wichita, Chairman

1. Notes on Some Cave Bats of Kansas. C. W. Hibbard, U. of K.
2. Reproduction System of *Gryllus assimilis* Fabr. Liza Spann. U. of K.
3. A New Cestode from a Bat. S. L. Loewen, Sterling Col.
4. Studies on the Resistance of Fowl Breeds to Parasitism. L. L. Eisenbrandt, J. H. Wilmoth, and Ivan Pratt, K. S. C.
5. Observations on Centrioles in Birds. W. J. Baumgartner, U. of K.
6. The Effects of Antuitrin "S" Injections into Ground Squirrels. B. L. Baker, K. S. C.
7. a. Descriptions of New Lizards of the Genus *Sceloporus* from Mexico and Southern United States.
   b. Notes on the Taxonomic Status of some Lizards of the Genus *Sceloporus* from Mexico.
   c. Notes on Some Lizards of the Genus *Phrynosoma* from Mexico. H. M. Smith, U. of K.
8. Additional Records of the Amphibians and Reptiles of the Central Prairie Region of the United States. C. E. Burt and W. L. Hoyle, Southwestern Col.
9. A Sex-limited Factor for Lowered Viability in the Grouse Locust *Paratettix texanus*. R. K. Nabours and Margaret Tabor, K. S. C.
10. Check-list of Reptiles and Amphibians of Ellis County, Kansas. L. A. Brennan, St. Joseph's Col., Hays.
11. On the Osteology of the Agamid Lizard, *Gonycephalus grandes*. D. H. Dunkle, U. of K.

CHEMISTRY PAPERS

Friday, April 27, 1:30 p. m., Science Hall, Room 306

W. W. Floyd, Ottawa, Chairman

1. Kojic Acid: A Review. H. N. Barham and B. L. Smits, K. S. C.
2. Concerning the Preparation of Some Diazo Thio Ethers of Thio Beta Napthol. J. T. Dunn, Jr., and W. A. Fletcher, U. of W.
3. Nitro Compounds as Oxidizing Agents. II. E. L. Martin and W. A. Fletcher, U. of K.
4. A New Method for the Use of Charcoal as a Decolorizing Agent. W. A. Fletcher, U. of W.
5. The Detection of Electrode Reactions by Means of the Haring Cell. J. E. Stareck and R. Taft. U. of K.
6. The Flocculation of Albumin by Electrolytes. P. V. Imes and R. Taft, U. of K.
7. The Effects of Synthetic Atmospheres of Nitrous Oxide and Oxygen Upon Animal Life. J. W. Hershey and L. A. Enberg, McPherson Col.
8. Thiazolidines and Thiazolidones. L. Oncley, Southwestern Col.
9. Analyses of Winfield Water. W. Wade and L. Oncley, Southwestern Col.
10. The Melting Points of Certain Metallic Benzoates. A. L. Snyder and L. Oncley, Southwestern Col.
11. On Some Derivatives of Salicylic Aldehyde. F. B. Dains and Sister Marie Stanislaus Smith, U. of K.
12. Victoria Blue BX as Internal Indicator in Ceriometry. J. M. Caldwell and Mary E. Weeks, U. of K.
13. Gold Prospects in Kansas. E. D. Kinney, U. of K.

PHYSICS PAPERS

Friday, April 27, 1:30 p. m., Science Hall, Room 204

G. W. Maxwell, Manhattan, Chairman (On leave of absence.)

Wm. H. Matthews, Pittsburg, Secretary and Acting Chairman

1. Instrumentation of Measurement and Control in an Oil Refinery. P. R. Hoyt, Wichita.
2. Photoelectric Properties of Cadmium Films. J. M. Schmidt and D. Roller, Tabor Col.
3. The Emissive Power of Liquid Metal at High Temperatures. C. Kaufman, Walton.
4. Measurements of High Resistance with Vacuum Tube Oscillator. L. R. Weber, Friends Univ.
5. The Interference of Subjective Harmonics. E. K. Chapin, K. S. C.
6. Some Elastic After Effects in Solids. H. D. Ayers, U. of W.
7. A study of the Near Ultra Violet Spectrum of Copper. R. H. Zinszer, Mass. Inst. Tech.
8. A Demonstration Experiment of Electrical Resonance. W. Good, K. S. T. C., Emporia.
9. Some Problems and Demonstrations in Physics. L. W. Hartel, K. S. C.
10. Tribo-luminescence of Barium Sulphide. C. J. Martinez, K. S. C.

PSYCHOLOGY PAPERS

Friday, April 27, 1:30 p. m., Administration Building, Room 204

J. B. Stroud, Emporia, Chairman

(Kansas Psychological Association: J. B. Stroud, president; H. E. Schrammel, Emporia, secretary.)

1. Psychology and Mental Hygiene in Kansas. B. A. Nash, U. of K.
2. An Economical Method of Scoring Tests with Differentially Weighted Items. J. C. Peterson, K. S. C.
3. Problems of the Psychological Clinic. Edwina A. Cowan, Friends Univ.
4. The Evaluation of Punishment and Reward in Learning the Maze by Human Subjects. A. A. Lind, F. H. K. S. C.
5. The Extension Psychological Clinic at Fort Hays Kansas State College. G. A. Kelly, F. H. K. S. C.
6. The Incidence of the Middle Child Among Delinquents as Compared to Incidence in the General Population and Among Problem Children. Bertha M. Pratt, Friends Univ.

JUNIOR ACADEMY OF SCIENCE PROGRAM

Friday, April 27, 1 p. m., Science Hall, Room 102

Jack Beamer, Lawrence, Chairman

(Junior Academy of Science: Hazel E. Branch, Wichita, chairman of the Academy's committee sponsoring Junior Academy: Jack Beamer, president; Horace H. Koepke, Junction City, secretary.)

1. Junior-Senior High School, Junction City:
   a. Construction and operation of an experimental electric arc furnace. Horace Koepke.
   b. Transformer Construction and Design. Richard Swenson.
2. Junior High School, Lawrence:
   a. Making a Reflecting Telescope. Maurice Jackson.
   b. Taxidermy. Bobbie Thompson.
   c. Cicadas. Jack Beamer.
3. Wichita High School North:
   a. Demonstration of Burning Air. Stanley Riley and Everett Barnes.
   b. A Garden Club Program in the High-school Science Club. Edna May Arnold.
   c. Dinosaur Models. Margaret Brown.
4. Wichita High School East:
   Liquid air demonstration:
   a. History of Liquid Air. Vernette Mueller.
   b. Demonstration of Air Pressure. Maurice Ransom.
   c. Freezing with Liquid Air. Elinor Brownlee.
   d. Burning with Liquid Air. Warren Wuhlschleger.
5. Induction of new clubs. Dr. J. Willard Hershey, President Kansas Academy.
6. Business; election of officers; announcement of the decision of the judges; adjournment.

GENERAL PAPERS AND BUSINESS

Saturday, April 28, 8:15 a. m., Auditorium

1. An Ecological Study of the Fishes of Mineral Lake, Cherokee County, Kansas. H. H. Hall, K. S. T. C., Pittsburg.
2. Worms in Hens' Eggs. J. E. Ackert, K. S. C.
3. The Scientific Friends of Sir Walter Scott. M. Elvira Weeks, U. of K.
4. Experiments with Neon Lamps. J. L. Bowman, McPherson Col.
5. Fluorides in Kansas Waters and Their Relations to Mottled Enamel. Selma Gottleib, Lawrence.
6. New Technique in X-ray Photography. J. T. Wilson, C. of E.
7. Changes in the Structure of the Thyroid Gland in Response to Large Doses of Irradiated Ergosterol. A. M. Lands, U. of K.
8. The Absorption of Short-chain Fatty Acids. R. H. Hughes, K. S. C.
9. Two New Genera of Felidæ from the Middle Pliocene of Kansas. C. W. Hibbard, U. of K.
10. A Study in Hawk Evaluation on One Square Mile of Mixed Prairie. L. D. Wooster, F. H. K. S. C.
11. Some Observations on the Uterine Tissue of Guinea Pigs Fed Varying Amounts of Vitamin C Supplements. Alice Brill, K. S. C.
12. The Effect of College Training Upon the Attitudes of College Students. J. B. Stroud and W. J. Boldt, K. S. T. C., Emporia, Kansas.
13. The Distribution of Chert Gravels in Lyon County. L. C. Wooster, K. S. T. C.
14. Value of a Self-scoring Device as a Method of Teaching. J. A. Brownlee, Wichita H. S.

ENTOMOLOGY PAPERS

Saturday, April 28, 10 a. m. and 1:30 p. m., Science Hall, Room 119

P. A. Readio, Lawrence, Kansas

(Kansas Entomological Society: P. A. Readio, president, H. R. Bryson, Manhattan, vice president; R. L. Parker, Manhattan, secretary-treasurer. Business meeting at 10 a. m. Papers (1-5) at 11 a. m. and (6-21) at 1:30 p. m.

1. Report of the Central States Entomologists' Meeting at Lafayette, Ind. H. B. Hungerford, U. of K.
2. Biology and Control of the Western Apple Curculio (*Tachypterellus quadrigibus magnus* List.) (Curculionidæ, Coleoptera.) (Lantern.) R. L. Parker, K. S. C.
3. Phyllophaga (Scarabæidæ, Coleoptera) in Kansas. Milton Sanderson, U. of K.
4. Preliminary Report on the Genus *Listronotus* (Curculionidæ, Coleoptera). L. S. Henderson, U. of K.
5. An Interesting Deformity in Some Larvæ of *Melanotus fissilis* Say (Elateridæ, Coleoptera). H. R. Bryson, K. S. C.
6. *Eurytoma tylodermatis* Ashm., *Microbracon variabilis* (Prov.) *Microbracon tachypteri* Mues. (Hymenoptera)—Parasites of the Apple Curculio. R. L. Parker and P. G. Lamerson, K. S. C.
7. Preliminary Survey of the Collembola of Kansas. Melvin Griffith, U. of K.
8. Some Recent Developments in Termite Control. Roger C. Smith, K. S. C.
9. Collecting Spiders. W. S. Wagner, U. of K.
10. A Report of the Codling Moth Conference at Lafayette, Ind., February 27, 1934. Geo. A. Dean, K. S. C.
11. The Genus *Enithares* (Notonectidæ, Hemiptera). H. T. Peters, U. of K.
12. Preliminary Studies on Microvelia (Veliidæ, Hemiptera). Porter McKinstry, U. of K.
13. Notes on the Chloropidæ (Diptera) of Kansas. Curtis W. Sabrosky, K. S. C.
14. Another Apple Pest in Kansas, *Ornix prunivorella* Chambers (Tineidæ, Lepidoptera), the Unspotted Tentiform Leaf-miner. L. M. Copenhafer, K. S. C.
15. A Preliminary Survey of the Issinæ (Fulgoridæ, Homoptera). Kathleen C. Doering, U. of K.
16. Resistance of Varieties of Species of Triticum (Gramineæ) to Hessian Fly. R. H. Painter, K. S. C.
17. The Life History of *Arytina amorphæ* (Chermidæ, Homoptera). W. F. Harms, U. of K.
18. Biological Control of Weeds by the Use of Insects, with Special Reference to the Cocklebur in Australia. Sam G. Kelly, K. S. C.
19. The Genus *Bythoscopus* (Cicadellidæ, Homoptera). P. B. Lawson, U. of K.
20. Some species of *Erythroneura* (Cicadellidæ, Homoptera) on *Cratægus*. R. H. Beamer and Melvin Griffith, U. of K.
21. The Gregarious Habits of Beetles. E. Graywood Smyth, Hacienda Cartavio, Trujillo, Peru.

Minutes of the Sixty-sixth Annual Meeting

The sixty-sixth annual meeting of the Academy was called to order at 9:00 a.m., April 27, 1934, in the auditorium of the Municipal University of Wichita, by President J. Willard Hershey. At 11:00 a.m. a short business session was held. The president appointed the following committees:

Resolutions: Smith, Weeks, Harnly.

Auditing: L. D. Wooster, Goldsmith.

Nominating: Agrelius, Baumgartner, Deere.

Necrology: Rankin, Nabours.

The entire program of the Academy was presented as printed with few exceptions.

At a meeting of the executive council at 9:30 p.m., April 27, in the Wichita High School East auditorium it was voted that the nominating committee present two names for each office in 1935. The secretary's invitation to the social science group to form a section of the Academy was approved.

The regular business meeting of the Academy was called to order by President Hershey at 9:20 a.m., April 28, in room 207, Science Hall. The following report of the secretary was read and accepted:

REPORT OF THE SECRETARY

Publication. One thousand copies of volume 36 were received from the Kimball Printing Company of Manhattan in December, 1933. The cost was $2.65 a page. Copies were sent to all members in good standing in 1933, and 575 copies were delivered to the three supporting institutions.

New Members. To date, April 28, 1934, 51 new members have joined the Academy. In the following list are included two who joined in 1933 after volume 36 was published:

Emporia (College of Emporia): W. M. Good, E. Kirkpatrick, F. Wyman, Jr.
Garden City (Junior College): H. B. Choguill.
Hays: H. W. Putnam.
Hillsboro (Tabor College): J. M. Schmidt.
Hutchinson (Bresee College): S. T. Ludwig.
Junction City: Junior-Senior High School Science Club.
Kansas City, Mo. (University of Kansas City): H. P. Brown, J. R. Jackson.
Lawrence (University of Kansas): J. M. Caldwell, W. Baxter, R. L. Dill, A. M. Lands, Kathryn Staley, A. W. McCullough, Kathryn Taggert, David H. Dunkle, R. H. Thompson.
La Crosse (Junior High School): A. A. Lind.
Lindsborg (Bethany College): Hazel Varnloff, Ethel M. Johnson.
Meade: H. E. Elliothorpe (1933).
Manhattan (Kansas State College): C. E. Aubel (1933), E. K. Chapin, R. H. Hughes, D. A. Wilbur, Margaret Tabor, Burton Baker.
McPherson (McPherson College): L. A. Enberg.
Pittsburg (Kansas State Teachers College): M. Jenkins, H. H. Hall, J. R. Wells, J. A. Trent.
Salina (Marymount College): Sister C. Giersch.
Sterling (Sterling College): A. Elbl, W. Higbee, G. L. Gill.
St. John (High School): C. V. Irvin.
Topeka: S. D. Flora.
Walton (High School): C. Kaufman.
Wichita: C. Daniels, H. Mack Sutter.
Wichita: High School East Chemistry Club.
Wichita (High School North): J. A. Glover.

Wichita (Friends University): J. E. Herbertson.
Wichita (University of Wichita): F. M. Brooks, Edith Cobden.
Wichita (Sacred Heart Junior College): Sister M. Aquinas.
Winfield (Southwestern College): León Snyder, Wayne Wade, W. L. Hoyle.
Dallas, Texas: O. Sanders.

SUMMARY OF MEMBERSHIP, 1928-1934

(Computed from published records and secretary's receipts. Revised to include payments of back dues.)

	1928	*1929*	*1930*	*1931*	*1932*	*1933*	*1934*
Annual members paid by time of meeting:							
Old	21	115	125	135	167	154	175
New	18	49	51	67	56	82	51
Totals	39	164	176	202	223	236	226
Annual members paid later for that year:							
Old	72	54	48	73	47	66	...
New	76	5	14	10	11	5	...
Total	148	59	62	83	58	71	...
Total annual membership:							
Old	93	169	173	208	215	220	...
New	94	54	65	77	66	87	...
Totals	187	223	238	285	281	307	...
Life and honorary	66	67	65	63	62	62	...
Total of all members,	253	290	303	348	343	369	...

NEW DEVELOPMENTS. This year, through the efforts of the committee on state aid, we received $300 from the state legislature for distribution of the Transactions. Doctor Baumgartner drew on the fund for the plates for volume 36 amounting to $156.40. The secretary drew on the fund for $143.60 for stamps, stamped envelopes, and postal cards. The postage requirements of other officers and the publication committee were supplied from this source.

The Academy has been approached by the social science workers of the state regarding the possibility of their joining the Academy and having a section for their papers, and these workers have been cordially invited to do this.

Respectfully submitted,

GEORGE E. JOHNSON, *Secretary.*

The representative of the Academy on the Council of the A. A. A. S. submitted the following report, which was accepted:

Your secretary served as representative of the Academy at the Chicago meeting of the A. A. A. S. in June and at the Boston meeting in December. Besides attendance at the council meetings the chief duty was to represent the Academy at the Academy Conference on December 28. The program this year was a paper on "The Credit Value of Laboratory Teaching," by Dr. E. C. L. Miller of the Virginia Academy. Each representative was asked to present to his Academy this problem of how many hours of laboratory teaching should be considered equal to one hour of classroom instruction for discussion or study by a committee.

GEORGE E. JOHNSON.

President Hershey reported that the Academy had been represented at the first centennary anniversary of the Société Havraise d'Etudes Diverses, at Havre, France, on June 24, 1933, by the American Consul, Edwin C. Kemp. The Kansas Academy was the only state academy represented. President Hershey displayed a letter from Mr. Kemp describing the celebration.

The following reports of the treasurer and the endowment committee were read and accepted:

REPORT OF TREASURER

April 15, 1933, to April 26, 1934

Receipts

Balance on hand, April 14, 1933	$127.00
Dues from members	353.00
Received from A. A. A. S.	62.50
Sale of reprints to members	369.12
Miscellaneous sale of reprints	.26
Kansas State College, Manhattan	200.00
Fort Hays Kansas State College	100.00
Principal and interest on certificate of deposit	102.00
Principal and interest on certificate of deposit	102.00
Refund on U. S. government bond purchase	11.25
Interest on endowment fund	43.73
Contributions to endowment fund	2.00
1933 appropriation by Kansas legislature	300.00
Total	$1,772.94

Disbursements

Kimball Printing Co.: Printing	$990.52
Clay Center Engraving Co.: Cuts	35.04
Mid-Western Engraving Co.: Cuts	121.36
Secretary's Office: Help (mimeographing, folding, addressing)	20.67
Postage (in part for other offices)	152.10
Supplies	6.97
Editor: Postage	2.02
Trip to Lawrence	1.50
Treasurer: Postage	4.94
Certificate of deposit, A-12702 to First National (Hays)	100.00
Certificate of deposit, A-12719 to First National (Hays)	100.00
Miss Harman: Expenses at A. A. A. S. meeting	7.50
Purchase of $150 3% U. S. Treasury bonds	160.00
Flowers for banquet	1.75
A. J. Griner: Lantern bulb	3.17
W. J. Baumgartner: Expense securing state aid	25.02
Democrat (McPherson): Letterheads	2.52
Elliott Stencil Co.: Stencils	1.90
Balance on hand	35.96
Total	$1,772.94

Supplementary Statement on Financial Condition of Academy

Balance on hand in checking account	$35.96	
Due from University of Kansas	200.00	
Total		$235.96
Payable to Kimball Printing Co	$152.00	
Payable to endowment fund	2.51	
Total		154.51
Net balance		$81.45

Respectfully submitted,
Harvey A. Zinszer, *Treasurer.*

REPORT OF ENDOWMENT COMMITTEE

RECEIPTS

Balance in general fund from previous earnings and contributions	$103.98
Contributions during 1933: C. F. Menninger, $1; R. B. Dunlevy, $1	2.00
Earnings for 1933	45.73
Total	$151.71

DISBURSEMENTS

Two U. S. 3 per cent treasury bonds (par value $150)	$148.75
Registering mail	.45
In general fund, balance	2.51
Total	

INVESTMENTS

4 shares (AC99-AC102) Morris Plan Co., Wichita, at 6%	$400.00
8 shares (No. 7859) Greene Co. B. and L. Assn., Springfield, at 6%	300.00
5 shares, Class C, Western Savings and Loan Assn., Kansas City	300.00
1 (No. 11859K) U. S. Treasury bond, 1951-1955 Series, at 3%	100.00
1 (No. 670L) U. S. Treasury bond, 1951-1955 Series, at 3%	50.00
In general fund	2.51
Total	$1,152.51

This year Greene county defaulted their spring interest installment of $9, payable March 1, 1934, and the Western Savings diminished their interest rate to 3 per cent. Total earnings of fund since last meeting, $45.73.

ZINSZER, BREWSTER, JOHNSON, GRIMES.

The auditing committee reported that the accounts of the treasurer and of the endowment committee had been checked and found correct.

The secretary raised the question as to whether the Academy preferred to have the funds withdrawn from the building and loan companies as soon as possible and invested in government bonds. Upon motion this question was referred back to the endowment committee.

The outgoing chairmen of sections announced the election of the following chairmen for 1934-'35:

Biology: L. E. Melchers, Kansas State College, and (vice chairman) C. E. Burt, Southwestern College.

Chemistry: L. Oncley, Southwestern College.

Physics: G. W. Maxwell, Kansas State College.

Psychology: Paul Murphy, Kansas State Teachers College, Pittsburg.

Entomology: H. R. Bryson, Kansas State College. (Reported later.)

Junior Academy: Hazel E. Branch, University of Wichita. (Appointed by President Matthews later.)

The attendance at the sectional meetings was reported as follows: Biology, 85 (and after dividing: Zoölogy, 62; Botany, 34); Chemistry, 60; Physics, 52; Psychology, 40; Junior Academy, 68; Entomology, 36.

The chairman of the Junior Academy Committee made the following report, which was accepted:

JUNIOR ACADEMY OF SCIENCE—THIRD ANNUAL MEETING

The program was held as already printed in this volume of the Transactions. Mr. C. H. Dresher, of McPherson, and Mr. S. J. Neher, of Portis, acted as judges of the papers and demonstrations and made the following awards:

First: Bobbie Thompson, Lawrence, "Taxidermy."

Second: Elinor Brownlee, Wichita, "Freezing with Liquid Air."

The chairman of the Junior Academy judged the many unusual exhibits which were observed by many throughout the day. The awards were:

First: Margaret Brown, Wichita High School North, "Models of Dinosaurs."

Second: Maxine Setzer (and assistants), Wichita High School East, "A Mounted Skeleton of a Cat."

Maurice Ransom, Wichita High School East, was elected president and Dan LaSchelle, Junction City Senior High School, was elected secretary for 1934-'35.

The following high-school science clubs are members of the Junior Academy of Science and each club is listed as a member of the Kansas Academy of Science in the membership list published in this volume: Manhattan, Shawnee Mission, Lawrence (Jr. H. S.), Wichita (East), Wichita (North), Junction City.

BRANCH, BARNHARDT, GLOVER, ELLIOTT AND WISMER.

The chairman of the publication committee read the following report, which was accepted:

REPORT OF THE PUBLICATION COMMITTEE

In view of the possibility of having volume 36 published by the state, the publication committee unanimously decided to consider W. J. Baumgartner as managing editor to keep in touch with the state printer. The manuscripts complete were turned over to Professor Baumgartner early in June. During the summer he had the plates and cuts made. The incoming state printer expected to print the volume, but owing to a decision of the attorney-general, this could not be done without legislation. As the legislature was not to meet until in November and the prior business would make it impossible for them to render any favorable decision in law in time to get the volume in circulation by the end of December, 1933, the publication committee took advice from the Executive Council and other particularly interested persons, and about the 20th of October decided to publish volume 36 of the Transactions immediately. Working at high speed, the Kimball press was able to get the volume in the hands of the Academy in the last week of December.

GATES, JOHNSON, BAUMGARTNER, TAFT, SPERRY.

The following report was made by the state aid committee, which was accepted:

REPORT OF STATE AID COMMITTEE

The special concern this year has been getting the state printer to resume the printing of the Transactions as he did from 1872 to 1922.

In June Doctor Gates left the manuscripts with the chairman, who, after securing bids from Topeka, Wichita and Clay Center, had the half-tone plates made by the Mid-continent Engraving Co., of Wichita, and the zinc etchings by the Clay Center Engraving Co.

Early in July the chairman called upon Mr. W. C. Austin, the new state printer, and again in August, when Mr. Austin agreed to print the 1933 volume of the Transactions, but adverse rulings by the attorney-general, the extra session of the legislature and shortage of funds prevented his starting the work. Because of these delays the publication committee met and decided to print privately and the materials were returned to Doctor Gates.

The chairman then worked with the state printer and secured passage, through the House, of an additional appropriation of $50,000 for the state printing plant, but this was lost in the Senate in the closing rush of the session.

On April 24 the state printer promised to print a volume of not over 300 pages if the manuscript would reach him about June 1. This was verified in a letter of April 26, stating that under the conditions just mentioned, "I feel that we will have no difficulty in handling this before the copy for the biennial reports come in."

This committee would recommend:

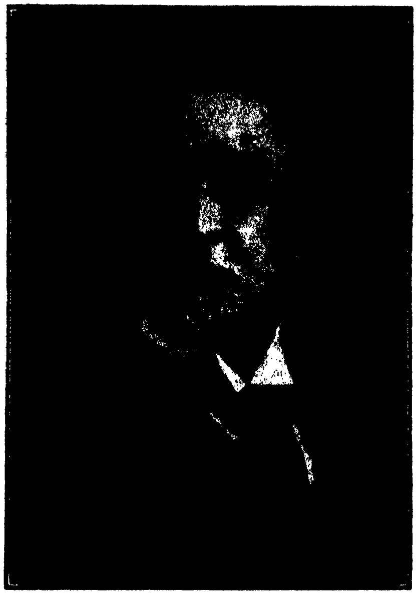
1. That manuscript and plates for about 275 pages be submitted to the state printer by June 1.
2. That if there are good papers which cannot be included in volume 37, a supplement be printed by the Academy.
3. That the Academy keep in touch with the legislature in order not to lose our appropriation.

BAUMGARTNER, KNAUS and WEDEL.

Dean Ackert expressed satisfaction with the promptness of private publication and with the arrangements with the three supporting state schools, and suggested that state printing is slow as evidenced by the time required for printing catalogues and circulars for the state institutions. Doctors Taft and L. D. Wooster suggested that this year had been one of unusual demand on the time of the state printer's office.

Dr. H. H. King of Kansas State College was elected a life member.

Dr. E. A. Marten, chairman of the local committee, reported that 164 persons attended the banquet, 100 attended the lecture by S. D. Flora, and



DR. E. H. S. BAILEY

DR. J. A. YATES

500-600 attended the lecture by R. C. Moore. He reported active work done by many members of the local committee. The report was accepted.

The resolutions committee offered the following resolutions, which were adopted:

Be it resolved that:

1. The Kansas Academy of Science extend its thanks and appreciation to the University of Wichita and Wichita East High School for the excellent facilities extended to the Academy for conducting the various sessions.
2. That we extend, through the secretary, our appreciation for the interesting and instructive lectures by Mr. Flora, Doctor Duley and Doctor Moore.
3. That we extend well-deserved thanks to the officers and various committees, particularly to Doctor Hershey and Doctor Johnson, for the splendid preparations for these meetings.
4. That we extend our congratulations to the University of Wichita upon securing the able services of President Jardine, and that we extend to him our best wishes for a happy and successful administration.
5. That the Kansas Academy of Science go on record as strongly opposed to the drastic cuts in funds for state and governmental research activities, believing that such steps represent the poorest type of economy.
6. That we extend our congratulations, through our secretary, to the newly formed Missouri and Minnesota Academies of Science and best wishes for a long and useful service to their states and to Science.

SMITH, WEEKS, HARNLY.

REPORT OF COMMITTEE ON NECROLOGY

The necrology committee presented the following obituaries:

EDGAR HENRY SUMMERFIELD BAILEY, 1848-1933

Edgar Henry Summerfield Bailey was born in the manufacturing village of Baileyville, near Middlefield, Conn., on September 17, 1848. After finishing the district school and graduating from Wesleyan Academy in Wilbraham, Mass., he taught in a little schoolhouse in Litchfield county, Connecticut. After four years the savings thus acquired enabled him to enroll as a student in the Sheffield Scientific School at Yale University, where he graduated from the chemistry course and remained for a year of graduate study.

In 1874 he became an instructor of chemistry at Lehigh University, where he acquired broad experience in the analysis of iron, steel and coal. In 1881 he studied under Rudolph Fittig at Strasbourg, and two years later he received the degree of Doctor of Philosophy from Illinois Wesleyan University.

In the fall of 1883 Doctor Bailey came to the University of Kansas as professor of general and analytical chemistry, toxicology, mineralogy, organic chemistry, blowpipe analysis, chemical philosophy, pharmacy, materia medica, and assaying. His inspiring leadership soon attracted an ever-increasing number of students and colleagues who immediately felt the warm friendliness of his personality, and now recall with pride his kind and cordial interest in their work and personal welfare.

In the early days Doctor Bailey served as consulting chemist for a large part of the Middle West, and thus helped to develop the salt, gypsum, oil, and gas industries. He published a number of books on analytical and food chemistry and more than one hundred scientific papers on such subjects as mineral waters, fuels, food adulteration, toxicology, and the dietaries of state institutions.

He was a life member of the Kansas Academy of Science and of the American Chemical Society, and a charter member of the Kansas City Section.

Doctor Bailey died on June 1, 1933.

JAMES ANDERSON YATES, 1865-1933

Dr. James Anderson Yates was born October 24, 1865, at Bush, in Laural county, Kentucky. Upon graduation from the rural school there he started a long career as a teacher. From 1885 to 1890 he studied at the University of Kentucky. After receiving his bachelor's degree in 1890 he became principal of Laural Seminary. In 1893 he became head of the Science Department at Cumberland College. On June 19, 1895, in Somerset, Ky., he was married to Miss Elizabeth Bryant, who survives.

In 1897 he left Cumberland College to become head of the Natural Science Department of Ottawa University, Ottawa, Kan., where he remained until 1907. He received his Master of Science degree from Kentucky University in 1899. During the same year he was a member of the Union Pacific fossil field expedition.

In 1907 Doctor Yates became head of the Physical Science Department of the Kansas State Teachers College at Pittsburg, Kan., in which position he remained until the time of his death.

Doctor Yates was well known in educational and scientific circles in Kansas and the nation. Doctor Yates became a member of the Kansas Academy of Science in 1898 and later became a life member. He held the office of president of the Academy in 1907. He was a fellow of the American Association for the Advancement of Science and of the National Educational Association. He was a member of the American Chemical Society and of the Kansas Association of Physical Science Teachers, of which he was a past president. He was a member of the American Vocational Association and directed the vocational and evening school work at Kansas State Teachers College, Pittsburg, Kan., for a number of years.

At the time of his death he was acting head of the graduate division and a member of the State Board of Education. In 1928 Doctor Yates took his sabbatical leave and enrolled at the University of Kentucky, where he received the degree of Doctor of Philosophy in the spring of 1929.

Upon motion it was approved that the secretary's railroad fare to the A. A. A. S. meeting at Boston be paid by the Academy.

Expenses of the chairman of the state aid committee ($10) were approved.

The president announced that it had been suggested that the editor represent the Academy at the Pittsburgh meeting of the A. A. A. S. and that his railroad fare be paid. Upon motion it was voted that the executive committee choose the representative and that Doctor Gates be kept in mind for the place.

The nominating committee, after having canvassed the ballots sent to them, presented the following nominations for officers: President, Wm. H. Matthews; first vice president, E. A. Marten; second vice president, W. J. Baumgartner; secretary, G. E. Johnson; treasurer, H. A. Zinszer; additional members of the executive council, J. W. Hershey, J. B. Stroud and R. H. Beamer.

Upon motion a unanimous ballot was cast for them and they were declared elected.

President-elect Matthews was called to the chair and the reading of papers was resumed.

The meeting adjourned at 12:10 p.m.

At a meeting of the new executive council at noon, April 28, and by correspondencé later, President-elect Matthews appointed the following committees:

Publication: Gates, Baumgartner, Johnson, Fletcher, Kelly, E. R. Lyon.

Endowment and Investments: Zinszer, Grimes, Johnson, Brewster.

Natural Areas and Ecology: Schoewe, Knaus, Hall, Michener.

Junior Academy: Hazel E. Branch.

Coördination of Scientific Groups: Harman, Hershey, Smith, L. R. Weber, Taft, Drake.

State Aid: Baumgartner, Knaus, Agrelius.

Membership: Johnson, Agrelius, Rankin, Dellinger, Stevens, Jewett.

Necrology: Rankin, Wilson, Melchers.

Resolutions: Agrelius, Harnly, Floyd.

GEORGE E. JOHNSON, *Secretary.*

PAPERS AND ABSTRACTS

SIXTY-SIXTH ANNUAL MEETING, WICHITA, 1934

Presidential Address:

The Historical Development of the Relationship of Gases to Animal Life

J. WILLARD HERSHEY, McPherson College, McPherson, Kan.

The earth does not end at its crust. It carries with it on its journey through space a mighty volume of gases known collectively as the atmosphere. However fast the earth flashes, however rapidly it spins, its force of gravity still grips these gases. One would think that as it rushes eighteen miles per second through space, the atmosphere would be swept off, but, in the first place, there is no friction in space, and, in the second place, gravity is quite strong enough to hold the gases.

The atmosphere extends not only to a great height, possible five hundred miles or more, but also downward, penetrating into the ground.

The gases of the atmosphere perform very important biological functions. Without them there could be neither animal nor plant life on the globe. All functions of life, motion, assimilation, reproduction, depend on a supply of these gases, and especially on a supply of oxygen.

Animals get the carbon they require by eating the carbon-containing plants. If there were not carbon dioxide in the air, plants could not get material to make their substance, and animals, in turn, could not get material to make theirs.

The life of man depends on air—mainly oxygen. Without oxygen there would be no fire, and without fire man might be a little better than a savage. Fire with its many consequences helped to lift man from savagery to civilization.

The most primitive man recognized a wind when out in it, but it took a Greek philosopher to tell us what it is—air in motion. But what is air? What is that invisible and odorless something we breathe and call atmosphere? What was its origin, etc.

Aristotle was one of the later Greeks who was not simply a philosopher as Socrates and Plato, but also a scientist. He studied about every subject known to the ancients. For many centuries after Aristotle people accepted what he said, and did not try very hard to study further. They thought that the giant mind of Aristotle had found out all there was to know. He was one of the first to suppose that there were four simple bodies—fire, air, earth, and water—of which all substances were composed. Aristotle who adopted these so-called elements into his system of natural philosophy did not look upon them as different kinds of matter, but as different properties carried about by one original matter.

"For more than twenty-two centuries, and perhaps much longer, it has been known that the air we breathe consists of at least two things, water vapor and whatever is left after the water is removed. And for more than two thousand years after the days of Aristotle that is all that was known about its composition." (*1*)

So far as we know at present there are ninety-two elements unequally distributed throughout the universe. During the time, for example, three billion

or more years by some means the primordial material of the earth was pulled off from or out of the sun. Of these ninety-two elements the ones that this paper is primarily interested in are those gases that are concerned with the respiration of animal life. Not until the latter part of the eighteenth century was any constituent of the air discovered in addition to water vapor.

The phlogiston theory stood in the way for the advancement of chemistry for many years. The name phlogiston was due to Stahl, and the theory to Becher, 1669. Stahl imagined that all combustible materials contain an invisible and weightless substance, which he named phlogiston (fire principle). When carbon burns very little ash remains; so carbon is very largely phlogiston.

Many famous chemists, Priestley, Scheele, Cavendish and others supported the phlogiston theory. It was an incorrect interpretation of combustion—a false theory. Priestley noted that the gas (oxygen) which he discovered caused a candle to burn much more brilliantly than was the case when air surrounded the flame. For this reason Priestley named the new gas "dephlogisticated air." The term "dephlogisticated" meant that the substance had been deprived of its content of phlogiston.

The phlogiston theory of combustion was only given up after oxygen had been discovered and Lavoisier had demonstrated the true nature of combustion. Priestley, whose discovery of oxygen contributed so much to the explanation of combustion, never gave up the phlogiston theory.

Robert Boyle (1627-'91) was a contemporary with Robert Hooke and John Mayow. Boyle, a wealthy bachelor, chemist and theologian came very near to finding one or more of the elements of the atmosphere during the seventeenth century. About the same time independent of Robert Boyle's work was that of John Mayow—a graduate in law at Oxford—who turned his attention to medicine and became a noted chemist, physician, and physiologist. Mayow concluded that the air consists of at least two portions, one that supports combustion and sustains life; and another part that does neither. He died at the age of thirty-six. If he had lived a few years longer, it might have been that his proofs would have been perfected and our knowledge of the composition of the atmosphere set forward almost one hundred years. John Mayow (*2, p. 16*) was born in 1643 and died in 1679, five years after the publication of his two essays on respiration.

Boyle's most famous discovery was that of the law which describes the behavior of gases under varying pressures and which still bears his name. Boyle's mother died when he was a child. He was a great reader and he could hardly be induced to join the games. He interested himself in science and theology.

Joseph Black (1728-1799): An eminent chemist and physician and the discoverer of carbon dioxide, which was the first of the relatively permanent gases found to be a constituent of the atmosphere and to be definitely recognized, if we accept Mayow's early work. (*2, p. 46.*) But we must remember that it had been prepared by Becker and Hales and had been doubtless obtained in an impure state by many others. It will be seen that Black's work was so complete and well established, the identity of this gas in so definite a manner, that his right to be named as its true discoverer can hardly be questioned.

Black was born near Bordeau in 1728. He began the investigations that led to the discovery of carbon dioxide in 1751, while a student of medicine in the University of Edinburgh, and published it in 1755 as his thesis for a degree. In 1778 he showed that the fixed air (carbon dioxide) was produced by fermentation, and by the burning of charcoal and the air from each of these sources shaken with lime water gave a turbidity. (*2, p. 69.*) He also showed that if the expired air from the lungs was passed through lime water it produced the same turbidity, therefore, this gas must contain some of the fixed air mentioned above. The air is diminished in volume by the breathing of the animal as it is by the burning of the candle.

Stevens Hales (1677-1761) was a British clergyman, biologist, chemist and inventor. His most important researches were on blood pressure, circulation of sap, respiration, and ventilation.

Priestley (*3*) said ever since he read Doctor Hales most excellent statistical essays that he was particularly struck with his experiments, which account is given in vol. I, p. 224, and vol. II, pp. 283 and 292, in which common air, and air generated from Walton pyrites, by spirit of nitre, made turbid red mixtures and in which part of the common air was absorbed.

Priestley began this work with a solution of brass on the 4th of June, 1772. He first found this remarkable species of air, only one effect of which was observed by Doctor Hales. So little attention was paid to it that, so far as he knew, no name had been given to it. Priestley gave it the name "nitrous air," called to-day nitric oxide. Priestley found that nitrous air was diminished with many substances, as oils, water and metals (due to the nitrous air—nitric oxide—changing to nitrous oxide). Neither Priestley nor Hales knew what was happening.

Daniel Rutherford (1749-1819): A Scottish physician, botanist and chemist. The statement that nitrogen was discovered in 1772 by Rutherford appears in most chemistry texts. Sir William Ramsay believed that Rutherford "may well be accredited with the discovery of nitrogen and that his thesis was in advance in the development of the theory of the true nature of air." However, all the facts and views recorded by Rutherford are to be found in Priestley's Memoirs (*4*) published and read six months before the publication of Rutherford's tract.

Rutherford's thesis was published on the discovery of nitrogen. His investigations were begun at the University of Edinburgh at the suggestion of Doctor Black, his teacher and the discoverer of carbon dioxide. Rutherford made a clear distinction between nitrogen and carbon dioxide which most of his contemporaries had failed to observe. Sir Henry Cavendish made this distinction somewhat earlier, but had failed to publish his results.

Priestley was born March 13, 1733, at Fieldhead, England, about six miles from Leeds. Priestley was a preacher by occupation and a chemist by recreation. He got oxygen, as we now know, by first burning mercury to an oxide and then decomposing that oxide by raising it to a high temperature with a burning lens. He came to America in 1795 and settled at Northumberland, near Philadelphia, where he died in 1804. His best-known experiment was the discovery of oxygen, which almost immediately followed Rutherford's discovery of nitrogen. Priestley discovered oxygen August 1, 1774, while Scheele had done so at least a year previous. Thus the priority of this dis-

covery rests with Scheele, but on the other hand, the priority of publication belongs to Priestley by about a year.

Priestley found that a mouse lived for half an hour in a portion of the new air (oxygen), and revived after being removed; whereas similar experiments with an equal volume of common air had shown that after respiring it for half the time (quarter of an hour) a mouse was indisputably dead.

Priestley had the curiosity to breathe some of this new air. "The feeling of it to my lungs was not sensibly different from that of common air, but I fancied that my breast felt peculiarly light and easy for some time afterwards. Who can tell but that in time this pure air may become a fashionable article in luxury? Hitherto only two mice and myself have had the privilege of breathing it."

Carl Wilhelm Scheele was born on the 9th of December, 1742, in Stratsund, Sweden. He was a professional chemist, so completely absorbed in his subject that he had little time for anything else. Scheele, near the beginning of this Treatise on Air and Fire, defines air. It is that fluid invisible substance which we continually breathe; which surrounds the whole surface of the earth, is very elastic, and possesses weight. Scheele died May 21, 1786.

Henry Cavendish (1731-1810), an English chemist and physicist, born at Nice, October, 1731. He was a very quiet and reserved man. It was said of him that he probably uttered fewer words in the course of his four score years than any man who ever lived so long—not even excepting the monks.

During the latter part of his life Cavendish (*5, p. 83*) was immensely rich. At the time of his death he was said to be worth a million and a quarter and was the largest holder of bank stocks in England. Cavendish, as you may suppose, could never be induced to sit for his portrait; but an artist who was bent upon having it managed to get near his subject unobserved, first sketching the three-cornered hat, then the great coat. He patiently watched his opportunity and inserted the profile between them. This I believe is the only authentic portrait of Cavendish.

Cavendish discovered nitrogen probably before Rutherford, but he did not publish his results. His scientific work is distinguished for the wideness of its range and for its extraordinary exactness and accuracy. His communications to the Royal Society in 1766 on chemistry of gases are among his chief titles to fame. He conducted experiments on "Factitious Airs," dealing mostly with inflammable air (hydrogen), which he was the first to recognize as a distinct substance, and "fixedair" (carbon dioxide).

He died as he lived, voluntarily severing every tie of human sympathy. When he found himself near his end, he called his servant to his bedside and said, "Mind what I say—I am going to die. When I am dead, but not till then, go to Lord Geo. Cavendish and tell him, 'Go!'" The dying man wished to be alone and the servant, who hesitated to leave him, was ordered from the room. In half an hour he returned to find that his master had turned his face to the wall and quietly passed away.

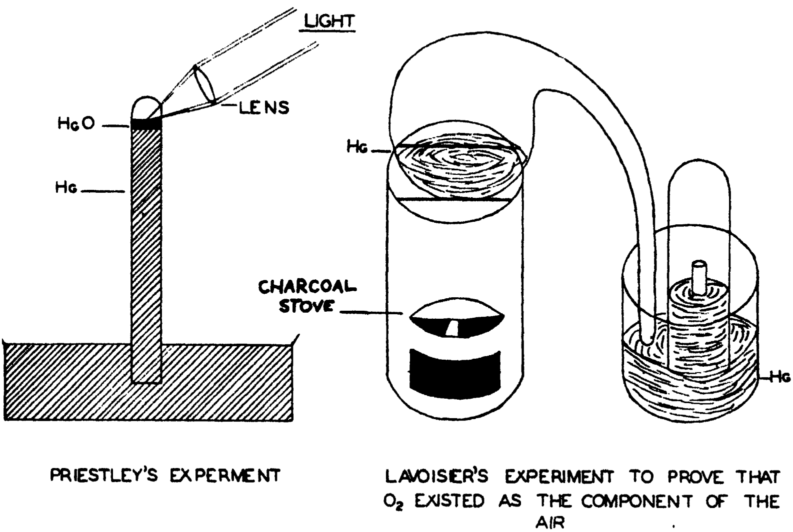
Auguste Lavoisier was born in Paris, 26th of August, 1743. His father was wealthy, and spared no expense on his education. He advanced in his field early in life.

Lavoisier (*2, p. 109*) published a paper in 1777. Its title was, "On the Combustion of Candles in Atmospheric Air, and Air Eminently Respirable." At

the zenith of his fame he was as much a dictator in the world of science as Napoleon became in the world of politics (*5, p. 125*).

Lavoisier heated mercury in contact with air in the retort and he continued the heating for twelve days. As a consequence of heating mercury in air it was noted by Lavoisier that one-fifth of the inclosed volume of air disappeared. In 1777 by this simple experiment Lavoisier proved that oxygen gas has existed as a component in the mixtures of gases which we call the atmosphere. The substance we now call oxygen—a name we owe to Lavoisier although discovered by Priestley, August 1, 1774. Lavoisier was called the "Father of Chemistry." He was guillotined in 1794 at the age of 51.

Up to the latter part of the nineteenth century it was supposed that the constituents of the air had all been discovered. But Lord Raleigh (1842-



F.G. 1. Diagrams of Priestley's and Lavoisier's experiments.

1919), an eminent British physicist, and Sir William Ramsay (1852-1916), an eminent British chemist, found that the supposed nitrogen of the air is in reality a mixture of nitrogen with a new gaseous element to which they gave the name argon.

In 1893 Lord Raleigh published a paper in which he mentioned that nitrogen prepared from ammonia, its compound with hydrogen, was somewhat lighter than atmospheric nitrogen. Ramsay asked and received permission from Raleigh to make experiments on nitrogen of the atmosphere. He finally heated magnesium, leaving a residue of gas known to-day as argon.

During the years of 1895-'98, that is, immediately after the discovery of argon, four additional inert gases, helium, neon, krypton, and xenon, were found by Sir Wm. Ramsay and his assistant, M. W. Travers, to be constituents of the atmosphere (*1, p. 9*). Helium was found as that portion of the atmosphere that is still gaseous while the rest has been chilled to liquids or solids;

and the others, neon, krypton and xenon, by fractional distillations of larger quantities of liquid air and liquid, impure of course.

NOTE.—The remainder of this address will be published in full in the May-June, 1934, number of *Current Research in Anesthesia and Analgesia*. Much of this material has been published in earlier numbers of these Transactions.

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Additional Archæological Notes on the Uintah Basin, in Northeastern Utah[1]

ALBERT B. REAGAN, PH. D., Ouray, Utah

Hill Canyon, as has been previously noted (*1*), is 45 miles about due south of Ouray, in the Uintah Basin, in northeastern Utah; and the head of Florence canyon is over the top of the East Tavaputs Plateau 30 miles still farther to the southward (see Fig. 1). This canyon and Chandler canyon, which parallels it, 8 miles to the northward, are simply earth gashes of probably three thousand or more feet in depth that drain westward to Green river. Each is about 15 miles in length and each has a narrow, fault valley in its center through which a beneficent perennial stream flows. Our work this year (1933) was principally directed to these two canyons, our party going down Florence canyon from Hill and Post canyons and returning via Chandler, with finds as follows:

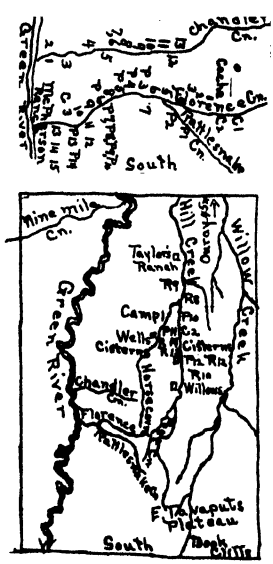

FIG. 1. Map of Florence and Chandler canyons, and adjacent regions.

FINDS IN FLORENCE CANYON

CLIFF HOUSES (including residences and granaries and an accompanying cache).

Cliff House 1. On the north side of the canyon, about 4 miles down the canyon from where the trail enters it from the plateau from the head of Post

1. The work covered by this report was done under a permit from the Secretary of the Interior and with the coöperation of the Laboratory of Anthropology at Santa Fe, New Mexico. The field helpers were Austin Wardle and his nephew, Mr. Alden Fenn, Mr. Wardle furnishing the outfit for the expedition. It should be further added that Miss Doratha Wilcox and her sister-in-law, Mrs. Pearl McPherson Wilcox, daughter of James McPherson, former owner of the ranch at the foot of the canyon, took horses and aided us in locating the various ruins that they had previously visited. Thanks are due to them and to the many other people who lent aid to us on this trip.

canyon, there are the remains of what was once a large residence cliff-house under an arched overhang, 100 feet above the valley and about 30 feet across its front, to which we could not get without ladders which we unluckily did not have. Only the west segment of the village now remains. It was originally two stories high. Two poles of the framework which were inclosed in the lower mortar walls at their base extend up to the rock roof 11 feet above the room wall that is now standing, showing that the building was that high originally. The story that now stands, though much dilapidated as a result of the wear of time, is between 4 and 5 feet in height. The front wall of this room was a daubed-over wattle-work. Its east wall, which was a partition, was of rock, which was laid in mud mortar. The roof, which was originally a chamber floor, was of quaking aspen (*Populus tremuloides*) poles, brush, and adobe mortar. The depth of this room was about 4 feet, the front 6 feet. No pottery and no pictographs were found. We secured a section of a pole that had fallen from this cliff house for a study of its rings of growth in an attempt to determine the age of the ruin.

High up above this cliff house and 100 feet east of it, in a niche, now inaccessible except by ropes from above, there is a small cache which belonged to the people of this house. It is almost triangular in ground plan, with a base of probably 4 feet. Though on the mesa front, it cannot be seen from the valley. It is still sealed.

Cliff House (Group) 2. (See Fig. 2.) Thirty feet above the valley floor, northwest of the creek, a half a mile down the canyon from cliff house 1, there is a chink-space under an overhang, 10 feet high, 6 feet deep, and 31 feet long. In this cave-space there are three storage granaries, each an oval-cone to a half-cone, or about the shape of an ancient beehive, set against the back wall. These are each very small, being not over 3 feet in longest diameter and from 2 to 3 feet in height. The middle and north granaries were laid up with rock and adobe mortar. The south, or smaller one, has its walls wholly of adobe. The middle and south one had each been roofed with a flat rock. The north one had a wattle-and-daub roof, with a small center hole over which a flat rock had formerly been placed. Sixteen cobs, 6 planting sticks, part of a metate, the rock lid to the entrance to this granary, 16.5 x 14 inches, and two disk rocks, each about a foot in diameter which were also probably used as lids to granaries, were found in the north room. Some cobs, a stone, granary lid 9 inches in diameter, and the blade of an ancient hoe were found in the middle granary; while the south one was empty.

Cliff House (Group) 3. (See Fig. 3.) In a similar cave-chink, along the same cliff-front and at the same level, 50 paces southwest of cliff house 2, there are five buildings, some of which are of the granary type. The walls of all the rooms are of rock, laid up with adobe mortar, as are two of the buildings in cliff house 2. The roofs were made of poles, over which mud and rock were placed, the rock having been set in mud to make the roofs. The center room has a hole in the roof for entrance. The south room was about 4 feet square and 3 feet high. It was full of rat dung, when visited. It had a cistern in its floor, somewhat squarish, 2.5 feet to a side, with a roundish front. It was sunk about a foot below the general level. In it were several artifacts and a part of a gray earthen pot with a handle. It also contained some much decayed planting sticks, a loom stick, which was probably used in making

rush mats, a grinding stone, a part of a rush mat which was tied together with a cotton-string cord (?), the string seeming to have been made from the cotton of the cottonwood trees of the region. The second room from the south had in it three greasewood planting sticks, a sandstone blade of an ancient hoe, many cobs, the rock lid to the opening, 9 inches in diameter, and a handle of a knife. The third room from the south was empty. The south room had back and side walls intact, but roof gone, and the next had the south wall and half of the roof missing; while the other buildings on the ledge were wholly down. It would seem that the people who used the build-

FIG. 2 (0-163). *Top row from left to right:* Handle of a knife, decayed planting sticks, and part of a rush mat and cornhusks from cliff house 3; cobs from cliff houses 2 and 3; Willow "rings" and straight, wall sticks from cliff house 2 in Chandler canyon; straw from an ancient bed in a protected place about 50 feet east of Cave 1 in (Hill) Horsecorn canyon; planting sticks from cliff house 2 in Florence canyon.
Middle row: A partly mummified foot of the mummy shown beneath it; a part of a much blackened-burned gray pot from cliff house 1 in Chandler canyon; parts of a gray pot from cliff house 3 in Florence canyon; lattice-work sticks from side-walls in cliff house 2 in Chandler canyon.
Lower row: A mummy from cave 1 in (Hill) Horsecorn canyon; a woven cord mat on which the mummy was lying in cave 1 above; the larger stones were lids to (cliff house) granaries and the others are grinding stones. Unless otherwise stated, all the artifacts above were obtained in Florence canyon.

ings of this group, as of those of cliff house 2, had their summer village at the base of the rock wall beneath the ledge below the houses, as the ledge here is an overhang over a wide sheltered space at its base.

Cliff House 4 (a resident village). (See Fig. 3.) A half a mile downstream below cliff houses 2 and 3 and one and a fourth miles above pictographic group F-P4 there is a large arched-out, overhang cave, 40 feet above the valley, in the south face of a rock ledge, north of the stream. This cave is 20 feet long across its front, 15 feet high and 10 feet deep. It is inaccessible, except by poles or a ladder. In it there still remain four rooms of a resident cliff house. The two rear rooms are set back on the two lower and larger rooms in true Pueblo style of the old times. The south front room has its front wall gone and shows an entrance hole in its roof. Much debris occurs in this room and about the buildings.

Cliff House (Group) 5. (See Fig. 3.) This group of five small cliff houses are on a ledge along the north wall of the canyon, 2.5 miles downstream from cliff house 3, and 1.5 miles upstream from cliff house 4. The ledge on which they are situated is about 400 feet above the valley and is about 100 feet in length, in an east-and-west direction. By a roundabout way over an ascending ledge these cliff houses can be reached with difficulty. They are all small, and were probably used principally as granaries. Beginning at the west end of the cliff space the writer has numbered the houses, a, b, c, d, and f. A and b are

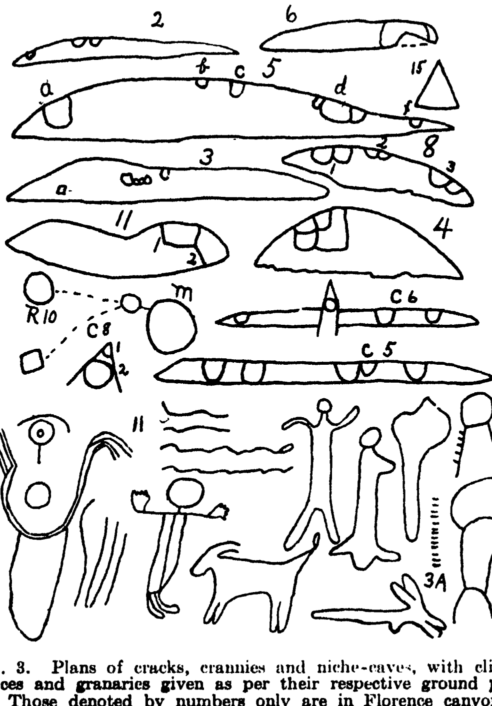

FIG. 3. Plans of cracks, crannies and niche-caves, with cliff-house residences and granaries given as per their respective ground plans of same. Those denoted by numbers only are in Florence canyon, those preceded by "c" are in Chandler canyon, and R 10 (Ruin 10) is in Hill canyon, "m" being the Mushroom Rock of that ruin around which several other structures are clustered. Pictographic group 11 is in Hill canyon, near Ruin 10. Explanations are found under the same cliff-house numbers in the text, as is ruin 10 and pictographic group 11, the last two being found in the Hill canyon section.

now dilapidated and c is now nearly gone. These three have been probably used only as granaries. D, whose entrance was through a hole in the roof, a flat rock being placed over the hole when not in use, has its east side now gone. It has an 8-foot front, is 4 feet high, and 4 feet deep, with a dilapidated room abutting it both on its east and west sides. Its inner walls are a plastered-over wattle-work which is nice and smooth. House f is squarish in ground plan, of approximately 4 feet to a side, the corners being rounded at the front. Its height is now about 3.5 feet, although it has suffered much from the ravages of time. The house marked "d" of this series was probably a residence.

Cliff House 6. (See Fig. 3.) This cliff house is about a mile below cliff house 5. The ledge on which it is built and which is about 20 feet above the valley floor is now almost gone. The little house now perched upon it so as to face the morning sun is about 4 feet across the front, 3 feet deep, and 4 feet high. Its front wall and roof are gone. It was built partly across a gap by the placing of poles for a floor support, some of which show that they had been burned to get them the right length and thickness, apparently evidence that the ancients did not possess ax-tools in this region in that far-off time. Furthermore, this building is probably the remains of a much larger house, parts of which time has carried away.

Cliff House 7. In a large crack 20 feet above the valley, a few hundred yards around a rock point, down the valley below cliff house 4, a wedged-rock has lodged; and on top of this there are several poles which seem to be the remains of the roof of a granary, now flattened. It should be added that there is a flying bird drawing (a circle with a headed, wavy line drawn through it) near and to the west of this cliff house.

Cliff House 8. (See Fig. 3.) A fourth of a mile below pictographic group F-P5 and three-fourths of a mile below cliff house 7 there is a cliff house, with a circular front, in a cranny in the rock wall 25 feet above the valley floor. This house, which has a pole floor over which 5 inches of mud was spread, was a small affair, 3 feet across the front, 2 feet high and 2 feet deep, placed on beams which extended from a wedge rock in the crack to chipped supports in the main wall on each side. A pole post had also been wedged in the crack as a support of the platform on which the house was placed. Below this house there is a small crack in the same cliff from which long sticks protrude.

Cliff House 9. This cliff house, which is about two miles down the canyon from cliff house 8, is in a small, longitudinal niche-cave, on the east side of a south projecting "promontory," on the north side of the creek, about 1,000 feet above the valley. (This "promontory" has pictographic groups F-P8 to F-P10 on its south point, and on the south it faces a slough. It should be added that from where the party started to climb to this niche-cave around the ledge to it is a good mile.) In it was found an ancient bed, a grain of corn on a stick, some charcoal, a grinding stone, and some scattered grains of corn.

Cliff House 10 (should be cave 3). This is a cave near cliff house 11, next to be described. It is 20 feet long, 4 feet high, and 6 feet deep. Charcoal was found in it under 2 feet of debris.

Cliff House 11. (See Fig. 3.) This house, which is about a half a mile below cliff house 9 and about a fourth of a mile below pictographic group F-P10, is an empty granary, 145 feet above the valley.

Cliff House (Group) 12. In pockets in the rock front, on the same level and about 25 feet northwest of cliff house 11, there are two small granaries, separated from each other by a space of about 10 feet. Each granary had about a two-and-a-half-foot front, was about 2 feet high, and about 2 feet deep. The north granary, in which we found a flatiron-shaped rock and a grinding stone, had had a flat rock lid over its top, which we saved.

Cliff House (Group) 13. On the north side of a projecting, blackish-sandstone ledge a half a mile about due south of the Wilcox ranch house (the Mc-

Pherson ranch house of the early settlement days) there is a small granary setting against the back wall in a blow-out pocket. It is 6 feet across its front, 2 feet high, and 2 feet deep. It contained only a single corncob.

In this same pocket-ledge, which is 15 feet above the valley floor, there is another granary on an out-projecting ledge, 6 feet above the first. In it we found some cobs, a pumpkin rind, a piece of a hoof or horn, with perforations, a squarish, woven, rush cord (?), a shale hoe blade, and two small rocks that had been used.

Cliff House 14. On the same ledge that cliff house 13 is on, about 400 yards toward Green river from that cliff house and at about the same level, there are the remains of a small granary of about a 4-foot front, 3 feet deep, and about 6 feet high.

Cliff House 15. (See Fig. 3.) Along the north wall, in a triangular corner, up an easterly leading side canyon, about a mile down Green river, 31 feet above ground, there are the remains of a cliff house (granary?) which probably had a 4-feet front, was 4 feet high, and probably 4 feet deep. It was on the whole somewhat equilateral triangular in shape in floor plan. Its walls were of stone and mortar. It is now down and its remains on the ledge are but a pile of rock, sticks, and poles. Just west of this cliff house is a large drawing of a water jug.

CAVES

Only three caves and cave groups were seen, one of which has been described as cliff house 10, above. The others are as follows:

Cave 1. This cave is on the north side of the trail just after descending to the valley from the Book Cliffs' heights to the eastward. It is under a large overhang whose walls are some smoked.

Cave (Group) 2. On the south side of an easterly projecting "promontory-like" ridge, just before coming to the Wilcox cross-canyon fence, about 2 miles after entering the canyon from the east, there are two large caves to the west of the creek, at least one of which had been used by ancient man. It had had holes drilled in its side-back walls for pole-rests in placing a roof and a front over the inhabited part of the cave. It might also be added that on the east wall of the canyon, about a half a mile below these caves, there are some crude pictographs. One set consists of two up-and-down, straight, parallel lines, each three feet in length. The writer was not close enough to the others to make them out.

PICTOGRAPHS

Sixteen pictographic groups, marked F-P1, F-P2, etc., on the negatives, in the order seen, were examined as follows, all the scenes being pecked except F-P1, which is a painted group.

F-P1 (see Fig. 4). This scene is on the south side of the canyon, 4 miles below cliff house 3. The upper figures are a circle, a foot wide, representing the sun, a fringed something, and 5 large blotches in a line, all in red; the central figure is a pecked centipede (?); and the lower figures, painted in white, are a lightning producer, 7 feet 3 inches long, like the Navajos use in the fire dance, but not completed, and a figure of the zigzag lightning itself, a foot and nine inches in length.

F-P2 (see Fig. 4). One hundred and fifty-one feet west of F-P1, at about the same level, there is a pecked scene, depicting an arrowhead (?), and six men who are represented as dancing, four with foxtails trailing behind them. It should be added that a summer house was probably built against the wall here, as was also probably the case with F-P1.

Fig. 4. Drawing of Pictographs. A is a flying bird near cliff house 7, and B is a drawing of a water jar near cliff house 15; and C is a drawing of spirals near cliff house 4, and B is a drawing on the south side of a ledge, 250 feet above the valley, straight across the canyon from cliff house 9. A and B are in Florence canyon (see cliff houses 7 and 15), and C and D, in Chandler. The other drawings are in Florence canyon, explanations of which are found under the same numbers preceded by "F-P" in the text.

F-P3 (see Fig. 4). On the south side of the canyon, a little above the talus slope level, 1.5 miles downstream from cliff house 4, there is a goat and a man figure, with a spiral head, besides several figures which are unintelligible.

F-P4 (see Fig. 4). This scene is at the ground level of the canyon, on the north side of the stream, a little above F-P3. Its principal figures are a goat with split hoofs shown, similar to those figured by Kidder and Guernsey (*2*), and a man with an elaborate, much side-tasseled headdress, shown in dancing

attitude and as wearing a kilt as is worn by the Pueblos and Hopis on special dance occasions.

F-P5 (see Figs. 4, 5). This pictographic group, which is about a fourth of a mile below cliff house 7, divides itself into three sections. The lower section, which is near the valley level, contains 5 goats, possibly 4 humans, 2 or 3 cactus plants (?), a tepee (?), 2 crude drawings of snakes, and several unintelligible things (see No. 5, Fig. 5); the second section, which is 30 feet around a rock corner, down the valley from the first, depicts a man with tasseled hat; and the third section, which is 30 feet directly above the first, contains two concentric circles, a bird's head, and several unintelligible things (see Fig. 5).

F-P6 (see Fig. 5). About a half a mile below cliff house 8 and about the

FIG. 5. Numbers 5, 6, the upper 8, and 12 are Florence canyon pictographic groups. The rest are Hill canyon scenes, of which No. 11 is described in this paper, as are the Florence canyon groups; the rest, in the writer's previous Hill canyon paper. Explanations are found under the same numbers in the respective papers and sections mentioned.

same distance above pictographic group F-P4 there is a pictographic scene north of the stream. It consists of a drawing of a much be-togged man, now much worn, six goats, and a dog (or a coyote) carrying something.

F-P7 (see Fig. 4). This group is just above the Wilcox pasture fence, a fourth of a mile below F-P4. It depicts 2 men, 2 goats with tails like dogs, and several other things of unknown purport.

F-P8 (see Figs. 4, 5). This scene is a fourth of a mile below F-P7. It depicts the sun riding on a goat, its neck resting on the animal's horns.

F-P9 (see Fig. 4). This drawing is 100 below F-P8. A drawing of the sun with outstretched hands, one grabbing at the moon, it would seem, are here depicted. A head, a goat, a snake, and several unintelligible things complete the group.

F-P10 (see Fig. 4). This group, which is 100 feet downstream from F-P9, is composed of a circle, a concentric circle, and a concentric circle with something in the shape of a cane passing across it through its center from the outside, this latter circle probably representing a bird.

F-P11 (see Fig. 4). This scene, which is near F-P10, is composed of a goat and two series of parallel, perpendicular, straight lines, through which a horizontal line is run.

F-P12 (see Fig. 5). This drawing is 1.5 miles up the canyon from the McPherson (Wilcox) ranch house. It is north of the creek, on a point of a south projecting ridge. It is composed of many, much-worn figures, many of which cannot be made out, some of the figures apparently showing superposition. Among those whose outlines can be traced are a jug, 6 goats, several dancers of the kachina type, 2 snakes, a warrior, a squirrel (?), a tree, and several unintelligible things. It should be added that many of the characters of this group are apparently of the Fremont culture, showing that this people were also in this region at one time.

F-P13 (see Fig. 4). This group is 25 feet south of F-P14, next to be described, is composed of 3 goats, a bird, and an arrow point (?)?

F-P14. This scene is on the west face of a black sandstone exposure an eighth of a mile northeast of the McPherson ranch house. The rock here is very hard and the drawings consequently poor. Four goats, and 7 kachina dancers are shown, one with kilt plainly depicted. The kilt makes one think of the present Pueblo costumes in dancing.

F-P15 (see Fig. 4). About an eighth of a mile south of the McPherson (Wilcox) ranch house two figures are drawn on the rocks, one of which is a kachina of large size. The rock has been split apart since the drawing was made.

F-P16. (See Fig. 5.) This pictographic group is near F-P15. The goat and water jar (the upper figures of the drawing) are probably ancient, the others probably modern.

ADDITIONAL NOTES ON THIS CANYON

Two mats, each about 2 by 3 feet in size, a human skeleton, and a twisted, cedar-bark rope ladder were found in one of the cliff houses of this canyon. They were lying about one of the granaries at the McPherson ranch for a long time before some unknown person removed them. There is also a large metate from one of the cliff houses of this canyon that is being used as a chicken trough in the Wilcox yard. Mrs. Wilcox gave it to us for scientific purposes, but as it weighed 60 pounds we could not transport it over the treacherous trail that leads out of the canyon. A high, flat-topped mesa near the McPherson ranch house also has loose rocks piled all around its edge, showing that it was used as a fortification by the ancients.

FINDS IN CHANDLER CANYON

From Florence canyon we proceeded up Green river 8 miles to Chandler canyon, beginning our work at the mouth of that canyon, numbering our finds in it from 1 up as we proceeded. No resident cliff houses were seen in this canyon. Instead, cliff-house granaries, which are here considered as cliff houses as they are edifices constructed in cliff spaces, were encountered here

and there. A rather large overhang cave near cliff house 2 had been dug into, but there is no indication that anything of value was found in it. Several other caves were noticed, but for lack of time they were not examined. Only two pictographic groups were seen (see C and D, Fig. 4), though we looked diligently for them. The first, which consists of a single spiral with a handle and a double spiral connected by a wavy line, is near cliff house 4; and the second, which is composed of a swastica and several unintelligible figures, is 250 feet above the valley, on the south side of the canyon, about straight across the cañyon from cliff house 9. The cliff-house granaries examined are as follows, the "C C H" with the respective numbers painted on the rocks beneath each one and also shown on the photographs standing for "Chandler canyon cliff house."

Cliff House 1. On the south side of the canyon a half a mile up from Green river there are two little cliff rooms, setting against the back wall on a shelf facing the noon-day sun, each about a half truncated-cone in shape, of about 3 feet in diameter and 1.5 feet in depth. Some stone was used in the walls. One tier near the top of the east building was made of little boulders of an inch in diameter. The west building had been set partly out over a niche in the rock, a timbered platform forming the floor support. A much-broken cooking jar was found in this cliff house; and a section of one of the poles was secured for a study of its rings. It might be added that a rattler tried to prevent us from examining this building till Mr. Wardle succeeded in killing it. It also might be further added that about straight across the valley from this ruin there is an ancient cache in a crack under a lodged boulder.

Cliff House 2. In a cranny in the rock front overlooking the valley, 40 feet above the ground, south of the creek, 250 feet upstream from cliff house 1, there is a small cliff house. Its sides were made, in part, with straight willow sticks tied together with willow bark, over which mud was plastered to complete the walls. Some of the above straight sticks, sections of the "tied" willow bark, and some "rings," three inches in diameter, made of willow limbs, were secured from this ruin.

Cliff House 3. This granary, which is about 100 feet east of cliff house 2, is back of a projecting ledge, facing east. It is 4 feet across its front, 2.5 feet deep and about as high. On the rock front and a little to the west of this granary there are the remains of two small caches in blow-out rock pockets, separated by a few feet, while stones were piled on the rock front above these, probably for bombardment of an enemy. A sandstone metate was found here; but as it was quite large and consequently very heavy we were compelled to leave it.

Cliff House (Group) 4. These cliff houses are in blow-out niches in a dark sandstone projection, north of the creek, 2 miles upstream from Big Spring, and about 10 miles below the junction of Moon Water creek with Chandler canyon. The upper blow-out on this ledge has 3 granaries, now down. Right below the west end of this blow-out, in another blow-out, there are the remains of another building, also now down; while a little lower down, in a blow-out, about under the east end of the last blow-out, there is another oval, truncated, cone-shaped room, whose front wall is now gone. Its base is practically 3 feet in diameter and it is 3 feet high. About 20 feet west of this

house there is another small granary, now wholly reduced to a flattened heap. Cedar poles were used in the construction of all the edifices here. A used stone and a milling stone were found at this cliff-house site.

Cliff House (Group) 5. (See Fig. 3.) Here the remains of four cliff houses can be seen on a ledge 500 feet above the valley and that much below the top of the mesa, south of the creek, a fourth of a mile up stream from cliff house 4. The ledge space is several hundred feet long, 4 to 6 feet wide, and about 5 feet high, now inaccessible. There were evidently more houses on this ledge in the long ago, both it and the houses upon it being now mostly gone, while the approach is wholly removed. Three of the houses are now reduced to a few poles and fragmentary segments of the foundations. The last building of the two buildings next the south house is still intact, in the shape of an oval cone set against the back wall; the room adjoining it on the west is now wholly down.

Cliff House (Group) 6. (See Fig. 3.) On an east-facing ledge across the canyon, an eighth of a mile upstream from cliff house 5, there are the remains of a small building in a crack. On an adjacent ledge, along the same rock ledge, on the same level just beneath this crack, there are three truncated, cone-shaped houses, one 10 feet to the south of the crack, and two about as far to the north of it. The house south of the house in the crack and the first one north of it on the ledge are still intact, the one north of the crack being about 3 feet in diameter in ground plan and probably 3 feet high. The north building on this ledge is now wholly flattened.

Cliff House 7. This is an oval, truncated, cone-shaped building in a blow-out pocket in a dark-colored sandstone ledge 100 feet above the valley, at the ledge front, eastward across the canyon, about 1,000 feet east of cliff house 6. It was not examined for lack of time.

Cliff House 8. (See Fig. 3). One hundred feet back and to the west of cliff house 6 there is a cliff house in a V-shaped crack. It is composed of two rooms, a lower room and then a smaller one set farther back and higher up in the crack.

Cliff House (Group) 9. Two hundred feet above the valley, in an inaccessible red sandstone ledge, on the same side of the canyon, a half a mile upstream from cliff house 8, there are two cone-shaped houses near each other, the cliff extending 125 feet above the shelf on which they are situated. The west house is now down, but the east one is still in its oval-truncated-cone shape. Near these cliff houses is the second pictographic group previously mentioned.

Cliff House 10. Poles of a flattened cliff house show on an east face of a point, 250 feet above the valley, on the north side of the canyon, about a mile upstream from cliff house 9.

Cliff House 11. On the east wall of a side canyon, north of the main canyon, a mile and a half upstream from cliff house 10, there is a small beehive-shaped cliff house in a blow-out pocket. It is now inaccessible except by a tedious climb and then only with ropes.

Cliff House (Group) 12. Under an overhanging ledge, 1,000 feet above the valley floor, a mile upstream from cliff house 11, there are the remains of two

quite small, walled-up granaries. The approach to them is now wholly gone. It would be impossible to get to them now, and even if one was there he could not get a footing.

Cliff House 13. This is a walled-in chink under an overhang, on the north side of the canyon, 75 feet above the valley floor, about a mile upstream from cliff house 12. Two central poles, at the front, were pressed into drilled holes at both the top and bottom of the chink and thereby formed a basis for the construction of the outer wall 3 feet high, across the triangular chink, part of which is now down. It could be reached only by ropes from above or by a very long ladder.

ADDITIONAL NOTES ON HILL CANYON (*1*)

(1) On a bluff right west of Long Mesa (Ruin 8 of the previous report), across Horsecorn wash, west of Austin Wardle's place, there is a small cache (granary) in a chink high up above the valley. This cache is small and its walled part much resembles a half of an old-fashioned beehive. Its walls are made of stone, laid up in mortar, and presents a fine view from the valley. It is four or five feet long in a north-south direction and is so low that there is barely space to crawl into it. It much resembles some of the granaries in the "Monuments" in northeastern Arizona, as will be mentioned later. Near this granary there is a tunnel and several small caves that were used by the ancients.

(2) Under an arch on the north side of Horsecorn wash, about a quarter of a mile southwest of Long Mesa (Ruin 8), there are the remains of several walls on a ledge, some distance above the valley floor. They may be the remains of granaries or of cliff-house residences. If the latter, time has worn away not only most of the buildings, but also most of the ledge-front on which they were erected, which would seem most likely the case.

(3) On a mesa tongue which projects into Horsecorn wash from the south, about a half a mile southwest of Long Mesa, there are the remains of two apparently natural, 30-gallon cisterns (tanks) which still hold water. The mesa tongue used to be reached by climbing a pole. The rotten pole was still against the wall. On the mesa top about these cisterns there have been found many arrowheads. Recently, two red, apparently proto-Kayenta potsherds were also found on this mesa, along with some plain, crudely made, undecorated gray pottery fragments. On the high mesa, due east of Long Mesa, there are also some natural tanks (cisterns), of quite large size, that were used by the ancients and which still hold water.

(4) In Cave 1 up Horsecorn wash (*1*, page 235, for a detailed description of this cave), about a half a mile above Long Mesa, a skeleton was found by a picnic party and later secured by the writer. The skeleton was in the very bottom of the debris, in a little hollow place, near the east end of the cave. It was headless and had its left arm and left leg missing. It was lying on its right side, with head to the west. Its right leg was flexed up against its chest, against which its right hand was also placed. The ribs were much broken and were partly missing. At death the corpse had been wrapped with a woven cord mat, and had considerable buckskin cord material placed about it. The wrapping over it had disappeared, but beneath it there were several detached pieces and also a very large whole piece, besides quite a bit of what

seems to have been a part of a cedar-bark-cord woven rabbit net. The right hand was intact, as was the right foot, which was detached. The latter showed the toenails and was mummified. The skeleton itself was also somewhat mummified. The hand had some black hair in it; and near it there was a small hank of black hair. The matting and netting beneath the skeleton was stuck fast to the rock underneath it. Besides some cobs, near the skeleton there was a part of an ancient stone knife 5 inches long, but of which both ends were gone.

(5) About 50 feet east of Cave 1 we dug up an ancient bed. It was under a projecting rock hood so that it was perfectly dry. The bed was under 7 inches of debris and was 6 inches in thickness. It was 4 feet wide and 10 feet long and was made of tall grass, with occasional shredded cedar bark and corn-husks. A pole underneath it, lengthwise, separated it into halves. A few cobs and some short sticks whose use cannot be conjectured were found about this site.

Cave 2. This cave is about a fourth of a mile up Hill canyon above Gilbert Wild's ranch and 1.5 miles below Mushroom Rock (Ruin 10; see Reagan [*1, p. 235*]). It is on the east side of a high bluff, on the north side of a side canyon of the main canyon, 400 feet above the mouth of the canyon. It is a large cave and was excavated by the Donald Scott party from the Peabody Museum. Its debris is about 2.5 feet thick. Cobs were found in this debris. Besides these, it contained a large cist, apparently of the Fremont culture type. It was made by setting flag rocks on end, was chinked with adobe mortar, and is reported to have been roofed in with adobe. As Doctor Scott will include a discussion of it in his report, it will not be further mentioned here.

Cave 3. This is a large cave at the valley level, on the north side of a side canyon about a half a mile east of Ruin 8 (Long Mesa) and Austin Wardle's place. It is now a shelter for cattle in winter. It was probably used by ancient man.

Ruin 10. Mushroom or Inverted Cone Ruin Village, the last ruin mentioned in Hill canyon in the writer's previous report, p. 235—the notes here are additional to those previously given (see Plate 3). The main ruin here, as previously given, was probably a religious building on the very top of Mushroom rock; while about the base of the rock there were several other buildings of small size which were also probably used in religious services connected with those conducted in the building on top of the rock itself. A room of about 9 feet in diameter abuts the rock's base at the northwest. Nearly 40 feet about west of its base there is a squarish building whose foundation is 9 feet to a side, near which there is an artificial depression of a depth of 2 feet; while 30 feet to the northwestward of the base of this rock are the remains of a circular building 15 feet in diameter, in which a cedar tree nearly a foot in diameter is now growing. While on the edge of the mesa front on which this (mushroom) rock is located there are yet the remains of piles of rocks that were placed there to be hurled off on enemies, or they are the remains of an ancient fort wall.

Ruin 11. Across Hill Creek valley, about a quarter of a mile northwestward from Ruin 10, there are the remains of an ancient cliff house under an

overhang which faces the morning sun. It is 125 feet long, 4 feet deep, and was 8 or 10 feet high in its heydey. Its front was made with laid-up rock, without adobe-mud chinking. A larger room at the south end and one at the north end can still be made out. This building was evidently a fort, which, from appearance, was hurriedly constructed to meet an emergency.

Ruin 12. On a projecting ledge, under an overhang on the south face of a cliff, 150 yards about due north of Ruin 10, there are the remains of a cliff house. It was quite small and was formerly rated as a granary. Nevertheless, it seems to have been a residence. However, a little higher up in the cliff to the west of this ruin there are the remains of a small granary in a blow-out pocket, the walls of which were constructed of adobe.

Ruin 13. Facing the morning sun in an overhang cave which is 50 feet long, 20 feet deep and 15 feet high, on the west side of the creek, 70 feet above the valley floor, about 3 miles south of Ruin 10, there is a cliff house 50 feet long, now mostly down, which shows no mortar chinking in its walls. In a rock chink on the same ledge, just south of this ruin, there is an adobe cache about 3 feet in diameter; and about 500 yards south of it there appears to have been a series of cliff houses and caches in blow-outs and in a large overhang cave just off and a little above the road, with, however, the debris, except for a pole or two all blown out.

Ruin 14. This cliff house ruin is west of the creek, about a mile north of Ruin 8. It is just below the rim of the mesa, immediately overlooking the valley, some 250 feet above the valley floor. It has a ten-foot front, a part of the front wall still being up. It was probably a granary.

Only two pictographic groups were examined in this canyon on this trip, as follows, the last group described in the writer's previous report (*1, p. 242*) being No. 9.

(10) (No. 11 of Fig. 5.) Fifteen feet above the valley floor, on a projecting rock point, west of the creek, 3 miles south of Austin Wardle's place and Ruin 8, there is a pictographic group consisting of 8 goats, or sheep, a man with a bow, a buffalo, and a kachina dancer. It should be added that someone has recently drawn a horse and several other figures on the rock face. These, however, are no part of the original drawing.

(11) (See Fig. 3.) This pictographic group is under a south-facing, overhanging rock ridge, an eighth of a mile, mostly west of Mushroom Rock (Ruin 10). Among the figures depicted here are 4 kachina dancers, a goat, several wavy lines, an "eye" (star?), the moon, the sun with a rainbow over it, and an unintelligible object, all of which are now very much worn.

REMARKS ON THE RUINS

Only two, or possibly three, resident cliff houses were found in Florence canyon and none in Chandler. On the other hand, 23 granaries were found in the former canyon, all of which, including the cliff-house residences, were on the north side of the canyon, except cliff houses (granaries) 13-15, which are in the lower line of cliffs that skirt Green river here on the east; while in the latter canyon 28 cliff-house granaries were examined, here found on both sides of the canyon. These ruins, also, are probably not more than half of the ancient edifices in the two canyons. One cache, 4 caves, and 16 pictographic

groups, all but one of which were on the north side of the canyon, were examined in Florence canyon, only 2 caves and 2 pictographic groups having been seen in Chandler canyon, while in Hill canyon we examined 6 ancient cisterns (tanks), 4 caches (granaries), 5 cliff houses and religious centers, and 2 pictographic groups.

The granaries in Florence and Chandler canyons were built in cracks, niches, crannies, on ledges under overhangs, and in one case, that of cliff house 9, in a cave. These were nearly all as nearly a truncated-oval cone as the space would permit such a building to be constructed, the entrance of most of them being through the top, over which a flat stone lid was placed when not in use. The somewhat circular base of each one was usually approximately 2.5 to 3 feet in diameter, and the height about 3 feet. However, some of the edifices had a squarish ground plan and were somewhat higher, with a flat roof, through which there was a central hole for entrance; while others were simply chink-spaces with walled-up fronts.

The granary rooms here described are similar to the granaries examined by Kidder and Guernsey (*2*, pp. 15-19, pl. 2) and by the writer (*3*) in Monument Valley in northeastern Arizona, and evidently were used by the same or a similar people and for the same purpose. Kidder and Guernsey's description of the granaries of northeastern Arizona, which would equally fit the similar one here, is as follows:

"In this region there are numerous one- and two-roomed structures and a few more pretentious buildings. The former were made by simply walling up the fronts of small natural caves or crannies in the rocks (pl. 2); their floors are not leveled, their roofs are seldom smoked, and there is little in the way of rubbish or potsherds in or about them to indicate that they were used as dwelling places. For this reason and because they are never found in groups or clusters (the Florence and Chandler canyon granaries, however, are often found both in groups and occasionally in clusters), but are scattered up and down the canyons with no apparent relation to one another, it seems probable that these structures were used as temporary storage places for harvested corn awaiting transportation to winter habitations."

It should be added that the writer's report on this Arizona region, above, shows that many of the ruins there were oval to old-fashioned beehive-shaped (often cut in half) edifices as are the granaries here in Florence and Chandler canyons.

As with the similar ruins in northeastern Arizona, the finds here seem to indicate that the people who utilized Florence and Chandler canyons had their permanent homes elsewhere, probably in Nine Mile canyon to the westward, or in the Hill canyon region; and that they resided in these canyons only in the farming season.

In all, 91 different artifactual finds were obtained, including a mummy. These, together with the pictographs and the ruins examined, would seem to indicate that the ancients who lived here were in a beginning phase of No. II Pueblo culture.

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NOTE.—For a complete bibliography of the papers that have appeared on the archæology of the Uintah Basin, the reader is referred to the writer's works: Summary of Archæological Finds in the Uintah Basin, in Utah, to date, Proc. Utah Acad. Sci., 10:8-10, Provo, Utah, 1933; and Anciently Inhabited Caves of the Vernal (Utah) District, with Some Additional Notes on Nine Mile Canyon, Northeast Utah, Trans. Kan. Acad. Sci., vol. 36:66-67, Manhattan, Kansas, 1933.

Plants Used by the Hoh and Quileute Indians

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While in charge of different tribes of West Coast Indians from 1905 to 1909 and in 1928 the writer made a study of the plants used by them. This included a study of the plants they used for food and medicine and those used in making baskets, mats, in house building, etc. The use of more than eighty plants are given, their descriptions, and uses to which the Indian put them, covering twenty-eight typewritten sheets. The paper is prepared that the Indians' uses of these plants will be made into a permanent record.

The Hoh and Quileute Indians of this article live on the west side of the Olympic peninsula, about due west of Seattle, Wash. The Quileutes occupy the village of La Push, which is near Mora, at the mouth of the Quillayute river, five miles down the coast from Cape Johnson and thirty-six miles down the coast southwest of Cape Flattery, while the Hohs live in the Indian village of Hoh at the mouth of the Hoh river, near Destruction Island, twelve miles southwest of La Push. These Indians were great users of the plants of the region in the old days, and still do use some of them.

For those who do not wish to look through the whole list for the Indian names of the plants of the region and the names of their different parts, a compiled list is here added:

NAMES OF THE PLANTS AND THEIR PARTS

(Given in the different ways the natives pronounce the same word, or the different words they use for the same thing.)

Leaf of a tree, klo-o-cheelth'
flowers, bee'h-hah'a
branch, hah-bah-ah'-ti-ut
bark, thlah-ah-wit
stump, tso-kots-a-pit, tsa-o-bo-wulth
root, tsapah-boh-wulth
leaves of spruce, e-yak-tsa-ti-it
wood, te-e-kah'
forest, hah-bah'-che-ohst-tle
tree, hah-bah, hah-bah 'uh; plural, hay-hay-bah 'uh (the "uh" a grunt)
grass, klo-ohb, klo-ob
maize, teh'-deh-cus 'chuk' thlay
red fir (*Pseudotsuga texifolia*), klay-hayts, kal-nayts
camas, "la camas" (pronounced lac 'a-mas), kwahl'-lu
red cedar (*Thuja plicata*), to dilth'
Sitka spruce (*Picea sitchensis*), yak-tsu
Mertins hemlock (*Tusga mertensiana*), teh-eh-thlu
common maple, Oregon maple (*Acer macrophyllum* Pursh), hkaks-to-ah-put
vine maple (*A. circinatum*), top-tse-yo-ka-put, top-tse-yo-ko-put
cottonwood (*Populus trichocarpa* Torr. and Gray), koh-oh-dohk
alder (*Alnus oregona*), ka-kal-e-ya, kah-kahl-e-yah
dogwood (*Cornus nuttallii* Audb.), che-chah'pulth
yew tree (*Taxus brevifolia* Nutt.), he'ah'
rhubarb, klopit
potato, kòw-wots
currants, kats'ah
devil club (*Echinopanax horridum* [Smith]), che-chah-pulth
thimble berry (*Rubus nutkanus*), ta-ka-chilth, tah-hah'-chilth

salmon berry (*R. spectabilis*), kood, chu-a-thlus-wa-put, chu-ah-thlu-wa-put
blackberry (*Rubus sp.*), bu-da-ba 'wh, bu-dah-ba 'uh
red elderberry (*Sambucus callicarpa* Greene), tse-ba-put, tse-bah, tse-e-ba, chlits-shalts-tse-tut, che-lits-shalts-tse-wit, tsu-bah-put
strawberry (*Fragaria sp.*), to-be-ya, to-be-yah
red huckleberry (*Lonicera hispidula* Dougl.), te-thlu-wot, te-thlo-ot-put; tethloh-oht
purple-blue huckleberry (*L. involucrata* Banks), t-wa 'duk
blue huckleberry (*Vaccinium* sp.), lah-wats-tsa-ke-le-dah-hut
crow berry (a shrub), ta-kah-chilth, kah-i-yok-ke-dah-hut
Oregon crabapple (*Pyrus diversifolia* Bong.), tsè-yok-yok-ke-dah-put ("put" equals shrub or bush)
crabapple (*P. rivularis* Dougl.), tse-yo-yo-'h'ke-dah-put
black-brown huckleberry, to-wah-duk, to-wa-duk
false mustard (an obnoxious weed), tad-dups-stat
thistle (general term), te-tse-ko-put
salal (*Gaultheria shallon* Gr.), kood-put ("kood" equals berries)
cascara sagrada (*Rhamnus purshiana* DC.), ah-ke-le
kinnikinnick (*Arctostaphylos uva-ursi* Spreng), ka-be-lk'wh
bearberry (*A. tomentosa* [Pursh] Dougl.), ah-'ke'le-put
horsetails (*Equisetum lævigatum* Braun), ba-a'-wh, tots-tse, and ba-ah'wh-tots-tse
fern, kah-a-kwa
fern, wot-tsa-a-balk
fern (a soft fern in the timber), pil'-la-pil'la, pil'la-pillah
fern (another soft fern), kaks-to-o-put
fern (*Pteridium aquilinum pubescens* Underw., a large fern that grows on the prairies, from the roots of which the Indians made flour in the old times), ka-kwa-put, hkah-kwah'put.

PLANTS USED BY THE HOH AND QUILEUTE INDIANS

The plants used by these two tribes, as known to the writer, are as follows: The plants used for medicinal purposes will be preceded by an asterisk (*). The Indian name of each plant will follow the common name or the scientific name, as the case may be.

Polypodiaceæ (Fern Family)

Polypodium occidentale (Hook) Maxon. Licorice Polypody. Common at Gray's Harbor, La Push, Quillayute, Forks, East Clallam, and Neah Bay. It is chewed much by the Indians.

**Phegopteris alpestris* (Hoppe) Mett. Indian name: pil-la-pil-lah. Common in the Olympic region.

Adiantum pedatum aleuticum Rupr. Maiden-hair fern. Indian name: ha-pal-pulth, or hah-polk-pulth. Common in shady places in rocky areas along the coast and elsewhere.

Pteridium aquilinum pubescens Underw. Braken fern. Indian name: ka-kwa-put, kah-a-kwa, wot-tsa-a-balk, hkak-kwah-put. This fern grows on the "prairies" of the region and burned-over places, especially in the middle upland regions. It is the fern of Forks and Quillayute prairies. It has also been carried to the beach with feed and appears in the old graveyard near where the old (Mr. Wesley Smith) schoolhouse used to be at La Push-Quillayute Indian village. At Forks prairie it grows as high as a horse. The burning of this fern year by year was what kept up the "prairies" of the peninsula and extended their area. The Indians burned the ferns for the purpose of clearing

out the prairies so they could shoot the deer and elk when they came to feed on the young fern sprouts. They also dug the roots of these ferns, pounded them to a pulp, dried the pulp, mixed it into a sort of dough and baked bread from it, which they claim was pretty good bread. Unluckily, the writer appeared on the scene too late to see any of this fern-paste bread.

The Indians have many myths about the ferns, but space will not permit relating them here.

Equisetaceæ

Equisetum lævigatum Braun. Scouring rush. Indian name: ba-ba'wh, tots-tse, bah-ah'wh, ba-ah'wh-tots-tse. Abundant along the coast.

Description: Perennial; stems 2 to 4 or even 5 feet high, all alike, evergreen, usually simple but sometimes branched, evenly 15 to 20 grooved; sheaths appressed, elongated, with 22 linear-awl-shaped caducous teeth; spike tipped with a rigid point; fruit produced in summer.

Equisetum hyemale L. A plant like the last above, but with a roughly tuberculate, dark-green stem.

The Indians of the coast dig the rootstocks of these two scouring rushes and eat them. They consider them a great delicacy. They also gather them to be eaten during several of their medicine ceremonies. They are said to be "good medicine." They are also eaten during the puberty ceremonies. They have a sweetish taste, not a bad taste. The writer has seen them dried in food preparation.

Taxaceæ (Yew Family)

Taxus brevifolia Nutt. Western Yew. Indian name: he-yah, he-ah. This was a valuable tree in the old times. From its wood the Indians made their bows and arrows, the disks used in their games, canoe paddles, and their whaling-harpoon stocks, and still make the latter of it. It was with a bow of this wood that the swamp wren is alleged to have shot an arrow to the heavens, over which Great Bear and Little Bear and all the other "animals" of the starry vault ascended from earth to heaven in the long ago. And as the arrow broke they have never been able to descend. This wood is used in the ceremonies. It also plays an important part in the myths of the Indians of the region.

Pinaceæ (Pine Family)

Juniperus scopulorum Sargent. Rocky Mountain Juniper. The twigs and berries of this plant are used in the Indian ceremonies.

Chamaecyparis nootkatensis (Lamb) Sudworth. Alaska cedar. Light canoe paddles are sometimes made of this tree. Canoes are also made from it.

**Thuja plicata* Donn. Giant Cedar. Indian name: to-dilth. This cedar differs from the cedar last above in its wood being reddish in color, in its larger size in circumference, and in its scales of the cone being oblong, not plicate.

Of this giant cedar the Indians make their dug-out canoes—canoes ranging in size from a little river canoe to an ocean whaling canoe that will hold ten whale hunters, or three tons of freight, made in each case from one piece (section) of log, and the canoe in each case being one continuous piece when finished, except just the front totem (river-deer) part. In making these canoes

in the old times it was a slow process of alternate burning and scraping with clam shells, and a possible chiseling with some wedge-shaped stone. To-day they are hued out with ax and Indian adz. A canoe for ocean use is now worth about $200.

There are many beautiful myths about the cedar and its uses, also one about why the canoe is shaped as it is.

In the olden times the Indians' dress was made, for the most part, of skins of wild animals and matted inner fibers of cedar bark. At that time the houses, which were of the "long house" style with roof sloping slightly one way, were also made of cedar clapboards, split and hewn with elk horn axes. In those times it was a great task to prepare these boards. So when the Indians moved, they tore the houses down and rebuilt them at their new abode. There were at least two kinds of these dwellings, the fish-drying-"potlatch" hall, and the dwelling proper. Their dishes were also made of wood. Their basketry was made from reeds (basket straw) or from split roots of young cedar trees. Ladles and spoons were made from goat horns, or cedar. Wodén cups filled with whale oil served as lamps, the inner bark of cedar, twisted into cords, served as lampwicks. And twisted cedar roots or cedar twigs served as ropes. The old people in the old times and even now use cedar bark head bands in the Ka-kla-kwal and Tsi-yuk dances. Before the white man came and even now, men, clad only in a blanket or totally naked, also go out early in the morning to some far-away place along the beach and take a cold bath, rubbing themselves dry with cedar twigs after the bath. Wild rye or anything else that will prick the skin is used at times instead of the cedar twigs. The juice of green cedar bark is boiled and used as medicine. The outer bark of the tree was also used in making wigwams, summer houses and hunting lodges. They shredded the inner bark of this species and wove it into sort of cloth, from which they made skirts for the women. They also lined their cradles with this bark, and wrapped their babies up in it before tying them in the same. A peculiar looking "overcoat" was made from this bark to be worn by the men while fishing in stormy weather.

**Pinus monticola* D. Don. Western white pine. Pine gum is used by the Indians both to chew and for coughs.

Pseudotsuga taxifolia (LaMarck) Britton. Red fir, Douglas fir. Indian name: klay-hayts, klay-nayts.

Description: Large; in youth, spruce-like and pyramidal, more spreading in old age. Leaves somewhat 2-ranked by a twist at the base.

Shakes and clapboards for houses were made from this tree in the old times. It was also used for wood, as it is now.

**Tsuga heterophylla* (Raf.) Sarg. Western hemlock. It is found throughout the region. It is a lowland tree, with cones 1 to 2 cm. long.

**Tsuga mertensiana* (Bong.) Sarg. Black hemlock, Merten's hemlock. Indian name: te-e-thlu.

Description: Characteristically, this tree differs from the western hemlock above in its being principally an alpine tree with appreciably longer cones.

The Indians use the bark of these two hemlock trees in tanning hides. Hemlock bark is also used as an emetic.

Picea sitchensis (Bong.) Carr. Sitka spruce. Indian name: Yak-tsu.

Description: Trees tall, pyramidal, with soft, white, tough timber; leaves flattened, somewhat two-ranked, and spirally arranged around branchlets.

Picea engelmannii (Engelm) Englemann spruce. This tree is subalpine, with height averaging about 90 feet; branches horizontal; bark thin, scaly, reddish to purple brown; branchlets pubescent; leaves quadrangular.

Shakes, clapboards, puncheon-planks, toys, etc., and wood are obtained from the spruce timber of the region, principally from the Sitka spruce. Spruce limbs and spruce roots are also shredded, pounded, and then twisted into cord and rope.

ARACEÆ FAMILY (ARUM FAMILY)

Lysichiton camtschatcense (L.) Schott. Skunk cabbage. Common in wet places everywhere from the mountain districts to the coast.

Description: A plant somewhat resembling a cabbage, but with larger leaves and no "head." Leaves large, ovate, cordate. Fruit a globular, oval to oval-elongated mass, composed of an enlarged, spongy spadix, inclosing the spherical seeds just beneath the surface; surface roughened with the persistent fleshy sepals and pyramidal styles. The plant has a strong odor. It grows from a thick root stock. It also reaches its greatest development near the seacoast.

In the spring the bear feed on this plant. The Indians also use its leaves. When roasting camas, wild onion, and garlic, they cover the cooking product over with layers of leaves of this plant. They then cover the whole over with a light layer of dirt and then over all they pile considerable wood. This they ignite and keep burning till the camas, onion, or wild garlic is cooked beneath it. They say that the "cabbage" gives a good flavor to the fruit. It is doubtful whether a white man would think so. They also wrap red elderberries in the leaves of this plant when preparing them by the native baking process above. They also wrap fruits, usually cooked fruits, in the leaves of this plant and bury the whole in the muck of some swampy region. In this way it is "canned" and it will keep till needed for future use. It is then dug up and recooked. In this way many things were preserved in the old times, and were palatable.

JUNCACEÆ (RUSH FAMILY)

**Juncus ensifolius* Wilks. Used as a medicine by the Indians.

LILIACEÆ (LILY FAMILY)

Allium cernuum Roth.
Allium crenulatum Weigand.
Allium acuminatum Hook.

The Indians collect the bulbs of wild onions, especially *A. cernuum* and *A. acuminatum* and bake them in a pit oven like the camas, as mentioned below. Thus prepared they are good eating.

Quamasia quamash (Pursh) Coville. Camas, called by the Indians "la camas" (pronounced as one word with accent on the first syllable, "lac'a-mas." Other similar plants are *Camassia esculenta* and *Scilla Fraseri*. The common names for these plants, besides the above, are camass, cammas, kammas, and

quamash, which are of Indian origin, though the "la camas" seems to be somewhat "Spanishized." *Q. quamash* is common wherever there is an open area, though most abundant in the "prairies," especially at Quillayute and Forks prairies.

Description: A bulbous-root plant, perennial; scape stout, over a foot in height; flowers dark blue, irregular, lower segment deflexed, segment not connivent in age, persistent; seeds shining; flowers slightly one sided in a simple raceme.

The bulb of this plant is used as food by the Indians of the whole coast. In preparing this food, a pit is dug in which a fire is built. On the fuel cobbles are piled, which, when heated to red heat, are covered over with wet leaves, brush, or grass. On this the bulbs are piled and over all wet leaves are spread to a thickness of, say, seven inches. Then over all, clay, earth or sand is heaped. Just before completing the covering over with earth, a quantity of water is poured on the cooking product and then when the covering is completed a small hole is left through the dirt-layer for the escape of steam. The cooking is then permitted to continue for about twenty-four hours. The product is removed through a hole dug through the top of the pit. The earth mound is left and the shifting sand fills up the hole from which the baked articles have been taken. The mound is then complete, a puzzle for future archeologists. (Clams and fruits were also prepared by the oven process.)

Oven mounds are scattered throughout the region and northward to the Fraser river country. Three types, pit mounds, stone inclosed mounds and sand and clay mounds, are represented.

The Indians have many myths about the camas plant, but space will not permit relating them here.

Xerophyllum tenex (Pursh) Nutt. Bear grass, Squaw grass, Basket grass. It is common in Clallam county; but more abundant towards Tahola (Granville), Quinault, and Grays Harbor. Its stem is 2 to 5 feet high; perianth-segments ½ inch long. It is much used by the natives in basket making throughout the peninsula, and a living is obtained by it for about half of the year. Grasses are also used in this basket-making process. This is the principal straw used, however. The Quillayute Indians obtained their "straw" from Quinault. The "straw," when used in weaving, is pared and scraped, also cut to the desired width by native implements. It is then neatly woven into baskets of all sizes, the smaller size being preferred. They are then sold. There is always a ready market for them.

SALICACEÆ (WILLOW FAMILY)

Salix sitchensis Sanson. Willow.

Description: Leaves entire, very silky beneath; stamen one; catkins appearing before the leaves.

The Indians use the small willow limbs of this plant and the other willows of the region in basket making. The limbs are split with the teeth, then pared and scraped to the proper thickness and width, then woven into baskets. Spruce roots and limbs are used in the same way and make very durable baskets.

**Populus trichocarpa* Torr & Gray. Indian name: ko-o-doke', koh-oh-dohk. Common along all the streams in their lower courses. The Indians make a tea of the bark and use it as medicine.

Description: Large tree; rough barked; petiole terete; capsule hairy, globose.

BETULACEÆ (BIRCH—ALDER FAMILY)

Alnus sinuata (Regal) Rydberg.

* *Alnus oregona* Nutt. Red alder. Indian name: Ka-kal'-e-ya', Kah-kahl'e-yah. This is a very common tree in the coast region, especially in the rich river valleys. It is extensively used as wood, being the best wood of the region. Tea is also made of its bark and used as medicine.

Description: A low, very much branched tree, often very crooked and sometimes even decumbent; leaves rusty pubescent on veins beneath, doubly dentate and often slightly lobed, dull of color; peduncles shorter than cones; winter buds acute.

In the old times the Indians placed the canoes of the dead, canoes containing corpses, up in alder trees among the leafy branches, where they tied them securely with spruce-root ropes. The writer saw several such "burials." The Indians seemed to prefer the alder to other trees for such interment.

URTICACEÆ (NETTLE FAMILY)

Urtica lyallii S. Wats. Nettle. Common everywhere in clearings and along the seacoast, reaching its greatest development on James Island opposite the Quillayute village of La Push. Where it grows thickest the squaws pull up the roots by hand and there make the best gardens. The roots were twisted into ropes in the old times, and both whites and Indians use the tops for greens. It has a very rank growth along the coast, its leaves also being thicker and more deeply cordate there.

Description: This plant differs from the other nettles principally in its having its leaves opposite, and in its possessing stinging hairs.

BERBERIDACEÆ (BARBERRY FAMILY)

**Berberis nervosa* Pursh. Oregon grape. Common everywhere. The Indians make jelly from the berries and also a tea medicine from the roots for a blood remedy.

Description: Small shrubs, with yellow flowers in bracteate racemes; wood yellow; stems simple, but only a few inches high; leaves 1 to 2 feet in length, rigid, 11 to 17 leaflets, palmately nerved; sepals, petals and stamens, 6 each; carpel 1, forming a berry.

BRASSICACEÆ (MUSTARD FAMILY)

Brassica campestris L. Turnip. Used by the Indians.

Brassica nigra (L.) Koch. Black mustard. A common weed at La Push, being brought there with feed and forage. The Indians use this plant both as greens and as medicine.

Description: Leaves petioled, cauline leaves not auricled or clasping; pods 4-angled, three-fourths inch long; beak of pod very short.

Brassica arvensis (L.) B.S.P. Charlock. A common weed, having been brought into the region with forage and feed.

Description: This plant is very similar to *B. nigra*, but with beak of pod long, about equaling the fertile portion.

Brassica alba L. White mustard. Indian name: tad-dups'stat. Also the name of a false mustard—an obnoxious weed that grows in the region. The white mustard escaped from cultivation in the school garden at La Push. It was also seen to be a weed in several homestead clearings in the region.

Description: Pods bristly, ascending on a spreading pedicel; leaves pinnatified; seeds pale.

The *Brassica* species above are used as greens and in flavoring, also as medicine.

Lepidium menziesii DC. Peppergrass. Common in all cleared places. It is eaten raw by the Indians and is also eaten as greens.

Description: Plant hispid to pubescent; petals none to occasionally present; pods glabrous, not margined except for very short teeth near the summit; basal leaves pinnately parted, pubescent; flowers white; pod emarginately 2-winged at the summit; cells 1-seeded.

GROSSULARIACEÆ (CURRANT FAMILY)

Currant, Gooseberry. Indian name: kats-ah

Ribes lobbii. A. Gray. Common.

Description: Flowers ¾ inch long, dark purple to white; anthers oval, very obtuse, white; calyx tube campanulate to cylindrical; berries warty, glandular. The flowers of this species are 1 to 4 on a pedicel. The leaves are plicate in the bud and the stems of the plant are armed with spines.

Ribes divaricatum Dougl.

Description: A plant very similar to *R. lobbii,* but differs from it in its having flowers greenish, broader calyx lobes, and in its having smoother berries.

Ribes lacustre (Pers.). Found principally in the mountain districts.

Description: Plant low; leaves downy to nearly glabrous; flowers in a peduncled raceme, numerous, nodding; calyx tube to saucer shaped; berries black, shading into red, glandular.

Ribes bracteosum Dougl. Very common.

Ribes howellii Greene.

Description: A plant resembling *R. bracteosum,* but differing from it principally in having its racemes pendant.

Ribes sanguineum Pursh. Red flowering currant. Common in the middle and lower reaches of the region.

Description: Leaves obtusely three-lobed to five-lobed; flowers red, varying towards white; the many flowered racemes drooping.

Currants are gathered by the Indians and eaten raw. They are also stewed and eaten, or canned for future use. They were quite extensively used in the old times.

ROSACEÆ (ROSE FAMILY)

Rubus lasiococcus A. Gray. Common.

Description: A stout, trailing, unarmed herb; leaves mostly 3- to 5-lobed; carpel-fruit tomentose.

Rubus nivalis Dougl. Common on the ridges toward Oberg's place.

Description: Biennial, trailing shrub, frutescent; leaves cordate, 3-lobed; sharply toothed; glabrous; petioles and veins of leaves armed with prickles; fruit red.

Rubus macropetalus Dougl. Dewberry. Common.

Description: This plant differs from *R. nivalis* in having dull leaves, 3- to 5-foliate, and black colored berries.

Rubus parviflorus Nutt. Thimbleberry. Indian name: tah-ah-chilth, tah-hah-chilth. Common everywhere.

Description: An erect shrub of 5 to 7 feet high; leaves 3- to 5-lobed; stem perennial, unarmed; fruit dark to light red, thimble-shaped when removed from the plant.

Rubus spectabilis Pursh. Salmonberry. Indian name: chu-ah-thlus-wah-put, kood, chu-ah-thlu'wah-put. Common everywhere and very prolific.

Description: Flowers large, red-purple; fruit salmon-egg color, ranging from yellow to crimson; leaves 3- to 5-foliate; stems prickly, biennial.

Rubus strigosus Michx. Red raspberry. Not common.

Rubus leucodermis Dougl. Blackcap. Common.

Description: Leaflets white, tomentose beneath; leaves 3- to 5-foliate; prickly stems, glaucous; flowers white; berry cap-shaped, black.

Rubus laciniatus Willd. Evergreen blackberry. Indian name: bu-dah-ba'h. Common on ridges near Oberg's place and about Beaver.

Description: Leaves 3- to 5-foliate; stems perennial, prickly; flowers white; berry cylindrical, black.

The *Rubus* species above are all gathered by the Indians and eaten raw. They are also stewed and eaten at once or canned for future use. The method of preparing the salmonberry has been previously described. Salmonberry sprouts were also used in the courting ceremonies in the long ago.

Rosa gymnocarpa Nutt. Common.

Description: Flowers large (one-sixth to one-fourth inch broad), solitary; calyx lobes persistent; stipules broad; fruit globose; spines stout.

Rosa pisocarpa A. Gray. Rare.

Description: Flowers in corymbs; fruit globose.

The fruit of the rose is usually picked and eaten at once. It is also plucked in winter and eaten, the Indians saying it has a better flavor then than earlier in the year.

Fragaria chiloensis (L.) Duch. Strawberry. Indian name: tsa-e-bah, chlits-shalts-tse-tut, to-be-yah. Common in all untimbered, nonswampy places, especially near the coast, growing even on the sandy beaches at La Push.

Description: Leaves thick, dark green, shining, strongly reticulate beneath, broadly obcordate in shape; plant densely villous in general, with silky hairs; flowers large; fruit ovate; akenes deeply pitted.

The natives highly prize this strawberry and annually scour the whole country for it. It is eaten raw and also stewed. In the old times it was "canned" by the skunk-cabbage-muck process.

MALACEÆ (APPLE FAMILY)

Amelanchier florida Lindl. Serviceberry. Common.

Description: A small shrub with pale twigs; leaves tomentose beneath when young, serrate only toward the apex; flowers racemose; calyx tube campanulate, limb 5-parted, persistent; petals 5, oblong, ascending; carpels 3 to 5; fruit berrylike, purplish, edible. This plant is readily distinguishable by its pale twigs and white, racemose flowers.

The fruit is eaten by the natives.

* *Pyrus diversifolia* Bong. Crabapple. Indian name: tse-yo-yo-'k-ke-day-put ("put" equals shrub). Common from the head of Hoh river, especially along its western branch, to the coast. At La Push it grows in a semiswampy region to the east of the old Wesley Smith schoolhouse site. There are also several patches of the species growing at Quillayute prairie, the largest covering about two acres, two miles east of the Quillayute post office. The Indians eat the fruit of this plant; except currants and gooseberries it is almost the only sour thing which the writer knows they eat. They also use the bark of its roots as medicine, the bark of its limbs and trunk also sometimes being used. Crabapple tea is also given as a remedy for gonorrhea.

Description: A crooked, very much-branched shrub to low tree, growing in dense thickets on bottom lands that are exceptionally wet. Flowers corymbose; fruit oblong, fleshy; carpels papery; leaves simple. The flowers are white to tinged with rose.

Pyrus occidentalis S. Wats. Mountain ash. Common. The Indians use the wood of this tree for various purposes. The fruit is also used.

Description: Leaves pinnate, leaflets dull, serrate near apex; flowers corymbose; fruit globose, purple, glaucus; carpels papery.

PRUNACEAE (PLUM FAMILY)

* *Prunus emarginata villosa* Sudw. Cherry. Common. The fruit is made into jelly, etc. The bark is also used as medicine, being pounded and made into a tea. A decoction was made from the bark and used as a blood remedy.

Description: A tree (shrub) 6 to 8 feet high; bark cherry color on trunk, on branches chestnut brown; branches of tree slender; leaves oblong-obcordate to oblong-oblanceolate; inflorescence a 6- to 12-flowered corymb; flowers white, ½ inch broad; fruit globose, bright red; leaves somewhat villous.

Osmaronia cerasiformis (Torr. & Gray) Greene. Rather common, but not much used by the natives.

Description: This plan, which is known as the oso berry, is a shrub about 15 feet in height; leaves broadly lanceolate; flowers greenish in racemes, appearing with the branchlets from buds; fruit a blue-black drupe, bitter.

EMPETRACEÆ (CROWBERRY FAMILY)

Empetrum nigrum L. Crowberry. Indian name: ta-kah-chilth. Common. The berries are used some by the Indians.

Description: A low, spreading, procumbent evergreen; leaves linear-oblong, scattered; foliage resembling that of the heaths; flowers scattered and solitary in the axis; sepals 3, petal-like; fruit drupaceous of the *Arctostaphylos* type, black.

ACERACEÆ (MAPLE FAMILY)

Acer macrophyllum Pursh. Oregon maple. Indian name: hkaks-to-ah-put. Common.

Description: This is a large-leafed maple; leaves 6 to 10 inches in diameter, deeply 3-cleft; flowers in racemes, fragrant, yellow; fruit hispid to densely hairy; wings 1.5 inches long, smooth. The tree averages about ten inches in diameter.

Acer circinatum Pursh. Vine maple. Indian name: top'tse-yo-ka'put. Common everywhere from timber line to the coast, growing usually on rich soil, often in low, wet places.

Description: A small, erect to decumbent tree; leaves 3 to 5 inches broad, 7- to 9-lobed, lobes sharply serrate; corymbs on slender 2-leaved branchlets 10- to 20-flowered; sepals reddish purple; petals shorter than the sepals, greenish; fruit glabrous; fruit wings widely spreading.

Maple wood is much used by the natives.

RHAMNACEÆ (BUCKTHORN FAMILY)

* *Rhamnus purshiana* DC. Cascara sagrada. Indian name: ak-ke-le. Common. The Indians at La Push (Quillayute) use this plant for medicine. They pare off the bark of the root or trunk, make a tea of it and then give it for a remedy for most any sort of a disease. They use it as a remedy for gonorrhea, taking it internally, and also use an injection of hot sea water for same. Their use of cascara sagrada, however, is not along scientific lines, even for an Indian. If a little is good, more is better. The herb man is just as liable to give his patient a 5-pound pail full of the tea to drink as not, provided he thinks that is the remedy needed, and deaths are often caused by overdosing the patient.

While the writer was at La Push (Quillayute), one of the old people got sick from eating too much spoiled fish. He needed a cathartic. The herb woman, in this instance, made a 5-pound pail almost full of very strong cascara sagrada tea and gave it to him. He drank it all, or most all of it, then died two minutes afterwards trying to throw it up. The writer appeared on the scene just as the aged man drank the last of the tea, and saw him strangle to death.

Description: A small tree with simple, undivided leaves; leaves elliptical, 3 to 7 inches long, deciduous, downy beneath; flowers with minute petals, mostly perfect; seeds convex on the back.

ARALIACEÆ (GINSENG FAMILY)

* *Echinopanax horridum* (Smith). Devil's club. Indian name: che-cha-pulth. A horrid pest everywhere. Used as medicine by the Indians.

Description: A shrub about 10 feet in height, with stem and foliage covered with long to very short spiny prickles; plant creeping at base, leafy at summit; leaves very large, palmately lobed; inflorescence a capitate umbel in a long raceme; fruit red, resembling the sumac in appearance, but more berrylike.

AMMIACEÆ (CELERY FAMILY)

Heracleum lanatum Michx. Common from timberline to James Island opposite the Indian village, and the coast in general. The Indians gather the shoots of this plant when young and eat them raw as greens. They will go miles for a mess of these shoots.

Description: A very large plant, strong-scented, erect, branching, grooved, wooly when matured; leaves usually 2-alternately compound; leaflets somewhat heart-shaped; inflorescence a many-rayed umbel; involucels many-leaved; calyx-teeth small to obsolete; fruit orbicular-elliptical; seeds flat and thin.

CORNACEÆ (DOGWOOD FAMILY)

* *Cornus occidentalis* (Torr. & Gray) Colville.

* *Cornus nuttallii* Audubon. Dogwood. Indian name: che-chah'-pulth. This plant is characteristic for its blooming in both fall and spring.

Description: A small tree, rarely a shrub; flowers in headlike cymes, surrounded by an involucre of 4 to 6 large, white, petallike (often reddish) bracts of from 2 to 3 inches in length and abruptly acute; petals 4, oblong-ovate, greenish; stamens 4, with slender filaments; styles slender; stigma capitate-truncate; fruit a large cluster of red berries.

**Cornus canadensis* L. Buck berry. Common.

Cornus berries are used in the ceremonies. The bitter bark is made into a tea and used as a tonic medicine. The leaves are also dried and smoked, producing an intoxicating effect, often being designated as "kinnikinnick."

ERICACEÆ (HEATH FAMILY)

Arbutus menziesii Pursh. Madrona. The leaves of this plant are sometimes smoked by the Indians.

Description: A red-barked tree; leaves evergreen, coriaceons, 3 to 5 inches long; flowers drooping, calyx small; corolla white, broad-ovoid; fruit a many-seeded berry of an orange-red color. The bark of the tree branches is shed annually.

Arcotostaphylos tomentosa (Pursh.) Dougl. Manzanita. Indian name: ah-ke'-le-put (also a name for *A.uva-ursi,* below). The Indians smoke the leaves of this plant.

Description: An erect shrub of some 6 feet in height. It resembles *A. menziesii,* above; but differs from it in its diminutive size and in the following: Bristly branchlets, arrow to ovate pale leaves, its flowers being in small racemes, and in its fleshly fruit being 1- to 10-seeded.

**Arctostaphylos uva-ursi* (L.) Spreng. Bearberry. Kinnikinnick. Indian name: kah-bee-lk'wh, kah-be-lk'wh (bah). Common, especially in the mountain districts. This plant is much used by the coast Indians. The leaves are dried and smoked by them the same as tobacco is smoked by the eastern Indians. It has strong narcotic properties and makes the smoker drunk if he indulges much, which the Indian will do if possible. This plant is also smoked as medicine. It is also smoked in some of the religious ceremonies. It is common to see some of the bunches of this plant hanging up in an Indian

house on the northwest coast just as one will see bunches of tobacco hanging up in a backwoods Kentucky home.

Some years ago an Indian of the Quillayute tribe, now living, or was only a few years ago, got intoxicated by smoking *A. uva-ursi* leaves and danced in the fire barefooted till the soles of his feet were burned to a crisp and his feet deformed for life. Some years previous another old Indian got drunk on the narcotic inhaled while smoking the leaves of this plant. As a result of being drunk, he fell in the fire, burned his feet almost off, burned his hands badly; also burned his nose completely off, also a part of his lips. In this condition he lived many years.

Description: A prostrate creeping shrub, rising to a foot or two in height; herbage green, glabrous; leaves oblong-spatulate, tapering to petiole, retuse at apex; flowers one-sixth inch long; otherwise similar to *A. tomentosa.* (Government Botanist Frederic V. Coville, of Washington, D. C., suggests that this plant will not produce intoxication unless mixed with tobacco. He has not spent thirty-five years with the Indians.)

**Gaultheria shallon* Pursh. Salal. Indian name: kood-put ("kood" equals berries). Common everywhere from timberline to the coast, reaching its greatest development near the coast, where it often reaches a height of ten feet and makes such dense underbrush as to make the woods impenetrable.

Description: Leaves evergreen, 2 to 4 inches long, serrulate; flowers drooping, axillary is slender but stiff, often branching, bracteate, viscid racemes; corolla urceolate; filaments hairy; fruit a black drupe.

**Gaultheria ovatifolia* A. Gray.

Description: A plant very similar to *G. shallon.* Leaves broadly ovate to subcordate; corolla campanulate; filaments glabrous.

The salal fruit, including that of *G. ovatifolia,* is eaten by both the Indians and whites. It is picked and eaten from the vine, also stewed and made into sauce and jelly. The roots and bark of these plants are also used as medicine, and the leaves are dried and smoked in lieu of kinnikinnick. Salal brush is also used in the Klukwalle dance ceremonies.

VACCINIACEÆ (BLUEBERRY FAMILY)

Vaccinium ovatum Pursh. Blueberry. Common everywhere.

Description: An erect shrub; leaves ovate to narrow-ovate, serrate, evergreen; flowers clustered; corolla cylindrical to urceolate to ovoid-globose, deeply 4-cleft, lobes reflexed, pale rose color; filaments hairy.

Vaccinium deliciosum Piper, probably a variety. Common in the mountain districts.

Description: Leaves deciduous, thick, pale and glaucescent; flowers cylindrical, solitary; corolla globose, mostly 5-lobed; calyx obscurely lobed; plant a shrub about 3 feet high.

Vaccinium macrophyllum (Hook). Indian name: to-wah'duk. Common in the mountain districts.

Description: A plant similar to *V. deliciosum,* but taller, with leaves serrate, and with blackish berries with bloom.

Vaccinium ovalifolium Smith. Blue huckleberry. Indian name: to-wah-duk. Common in the lower country.

Description: Smooth plant of from 4 to 12 feet in height; branchlets angled; leaves entire; berries blue with bloom.

Vaccinium parvifolium Smith. Red huckleberry. Indian name: te-thlu'wot, te-thlo-ot-put, te-thloh-ohnt. Common from timberline to the coast.

Description: A smooth plant of about 5 to 8 feet in height; branchlets green, jointed, sharply angled; berries red.

The huckleberries and blueberries above are picked and much used by both natives and whites. The berries are eaten raw, with cream and sugar, stewed and eaten as sauce, also canned. It is a common thing to see the natives picking these berries for winter use, for they are very plentiful.

Oxycoccus oxycoccus (A. Gray). Western cranberry. Grows everywhere in the swampy regions. The fruit is said to be used some by the natives.

Description: A trailing, slender, viny plant, in many respects resembling the vaccinium species, above. Leaves evergreen; flowers umbellate; corolla deeply 5-cleft, the lobes spreading; berry large, bright red.

LAMIACEÆ (MINT FAMILY)

**Nepeta cataria* L. Catnip. Escaped from cultivation. Used as a tea for infants.

**Mentha canadensis* L. Mint. Common.

Description: Villous; leaves oblong-ovate to approaching the oblong type; flowers in dense whorllike axillary clusters; corolla small, nearly regular, 4-lobed, upper lip plain; calyx 5-toothed; stamens 4; ovary 4-parted.

**Mentha piperita* L. Peppermint. Escaped from cultivation; at La Push and elsewhere.

Description: A glabrous plant, with a very pungent taste; leaves ovate-oblong to oblong-lanceolate, acute, sharply serrate; spikes narrow, loose.

These mints are used as smelling and rubbing medicine.

SCROPHULARIACEÆ (FIGWORT FAMILY)

Digitalis purpurea L. Foxglove. Everywhere, escaped from cultivation. The flowers of this plant are used in some of the dance ceremonies. They are also used for decoration purposes during special ceremonies and on special occasions.

Description: A tall stem with terminal spike of rose-white flowers, often spotted. The plant is now a common weed.

CAPRIFOLIACEÆ (HONEYSUCKLE FAMILY)

Symphoricarpos racemosus Michx. Snowberry, waxberry. Common. It is used in the ceremonies.

Description: Leaves very variable, smooth; corolla campanulate, hairy, narrow at base.

**Sambucus glauca* Nutt. Elder. Common everywhere, but reaches its greatest development along streams and in localities a short distance from the seashore.

Description: A shrub with white pith; leaves smooth, large; inflorescence a flat-topped cyme (or cymes), one-sided; fruit black with a white bloom. This plant is much like the eastern elder *S. canadensis*.

**Sambucus calliocarpa* Greene (?) Red elder (berry) tree. Indian name: Tse-bah'-put, tse-bah or che-lits-shalts-tse-wit, tse-e-bah, chlits-shalts-tse-tut ("put," "tut" and "chlits" equal tree). The common elder of the region from timberline to seashore, and very prolific, especially in river bottoms.

Description: A plant similar to *S. glauca*; but larger, with pyramidal inflorescence, and red to chestnut colored berries.

The fruit of this plant the Indians use as a sauce. They also gather the berries, dig a pit, heat a lot of cobble stones in the pit by burning a large quantity of wood in it, then over the rocks and live coals they place a thick layer of skunk-cabbage leaves. On these they place a bushel or more of the berries, cover the whole with another thick layer of leaves of the same plant and a thick coat of dirt over the whole. They then pile wood on the heap and ignite it and keep up this fire for about a day. The berries, being cooked in this way, are taken from the improvised "oven" and are ready for use, being seasoned with the flavor of skunk-cabbage leaves. The ancients also cooked the elderberry in the same manner in the old times, as many ancient over-pits dug up by the writer attest, the imprint of the refuse berries still being left over the layer of ashes. When it was wished to preserve the berries of this plant for winter use, the cooked product is wrapped in skunk-cabbage leaves and buried in the muck in some swampy place, to be dug up when needed. The advanced Indian of the coast now cans the berries in glass jars, as white people can fruit. The flavor of this berry either raw or cooked does not suit the taste of the white man; it is too strong and bitter. The bark and roots of this plant are used as medicine by the natives. The tea, made from steeping the bark or roots, is given to women during confinement. This tea is also given to cure coughs and colds.

COMPOSITÆ (THE COMPOSITE FAMILY)

**Taraxacum officinale* Weber. Common dandelion (in the eastern states). Brought to the region in forage-feed and in feed and seed grain. It is not plentiful, but is used as medicine by the Indians.

Description: Leaves radical, pinnatifid to runciate, smooth (pubescent sometimes when young); flowers yellow; outer involucre reflexed.

Cirsium arvense (L.) Canada Thistle.

Description: A slender perennial of about 2 feet in height, growing from a creeping rootstock, or roots that spread wonderfully; leaves oblong-lanceolate, slightly wooly beneath, sinuate-pinnatifid, prickly margined; flowers rose-colored.

Cirsium lanceolatum L. Bull thistle. A common pest in the open bottom lands and in cultivated fields at La Push and elsewhere in the region.

Description: Leaves decurrent on the stem, pinnatifid, prickly, rough and bristly above, wooly, hairy, and prickly beneath; flowers purple.

Carduus edulis (Nutt.) Greene. Indian name: te-tse'-ko-put. The young shoots of the thistle, especially those of *C. edulis*, are eaten as greens.

**Arctium minus* Schk. Burdock. Common in the region. Its leaves are made into a rubbing salve. A tea is also sometimes made from its leaves and roots.

Description: A stout plant growing to a height of 3 to 4 feet; leaves large, roundish-ovate, occasionally cut-toothed, smooth above, somewhat floccose-tementose beneath; peduncles short, slightly cottony beneath, inner scales purplish tipped, equalling the flower; flowers purple.

SOME SEA ALGÆ AND KELPS COMMON AT LA PUSH

Nereocystis luetkeana (?), kelp.
Fucus vesiculosus(?), kelp.
Fucus gigantea, giant kelp.
Chondrus crispus(?)
Odonthalia gmelinii(?)

Some of the natives are said to dry kelp and then eat it as white people do dried beef. The dried preparation is also dipped in whale oil and eaten. The Indians also used the large kelp as fishing lines in catching halibut and other fish on the "banks" off Cape Flattery.

FRAGMENTARY PLANT REMAINS FOUND IN THE MIDDENS

Gigantic kelp (*Fucus gigantea*); salmonberry (*Rubus spectabilis*); raspberry (*Rubus leucodermis* Dougl.) ?; *Vaccinium* species; camas (*Scilla fraseri*); half charred *Acer circinatum; Sambucus racemosa* Linn.; red-cedar wood fragments (*Thuja plicata*); salal (*Gaultheria shallon* Gr.); fern roots, roots of several kinds of seaweeds, roots of the eelgrass, thumb berry (*Rubus odoratus*); elder (*Arctostaphylos uva-ursi*).

Plant Sap and Juice: III. Data for the Spring of 1934

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The condition of the soil is the chief factor in the flow of sap preceding the bursting of the buds. Owing to the exceeding dryness of the soil this spring, most of the trees tapped did not yield sufficient sap for the various tests. The same trees (*1*) that were under observation in 1932 and 1933 were tapped in March and April, 1934.

More than 20 plants, mostly deciduous trees, yielded sap in 1932, only 4 gave appreciable quantities in 1933, and in 1934 only 2. This spring, the maple (*Acer saccharinum*) furnished samples March 25 and 26; and the grape (*Vitis palmata*), 15 days, from April 9 to 24, inclusive. The pH for the maple was 5.97, and for the grape from 6.35 to 5.50. These values coincided with those of previous years, the same individual plants having been tapped each year. The bursting of the buds marks the cessation of flow. It would seem that the water rises so slowly when the soil is dry that the pressure is not sufficient to make possible the collection of sap. March and April in 1932 were rather wet months, somewhat dry in 1933, and very dry in 1934. However, the pH values obtained during the past three years do not vary enough to warrant any conclusion in regard to rate of flow upon the hydrogen ion concentration.

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Kansas Botanical Notes, 1933 [1]

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The year 1933 started with a comparatively mild winter, followed by a dry spring. January was very warm, bringing into blossom the maple, *Acer saccharinum,* January 30, and the Chinese elm, *Ulmus pumila,* on February 2. Progress of vegetation was abruptly checked by cold weather in early February. March and April were dry and vegetation ran behind. At the end of April and in May the extraordinarily heavy late spring snows in the Rocky Mountains resulted in much cloudy and quite cool weather in Kansas almost through May. The result of these conditions was an abundance of vegetative growth, but flowering was decidedly less than normal. By the middle third of May the vegetation was still two weeks behind normal. The summer was hot and dry, the autumn continued the dryness so that by the end of the year the rainfall deficiency totaled many inches.

Among some of the interesting items during the year were the paucity of cocklebums and the extraordinary abundance of *Salvia pitcheri* during the fall of 1933. In many places whole hillsides, which normally had but few plants of this Salvia, were so covered as to give an impression of nearly solid blue at a short distance. It is quite possible that the unusually dry conditions which kept back the grasses may have been, at least in part, responsible for the display.

The curious plant *Eryngium leavenworthii* which is moderately abundant through the flint-hill region is present in the quarries from which railroads get rock for their ballast. As the result of ballasting operations a year or two ago, *Eryngium leavenworthii* has now been found in Cloud, Geary and Saline counties in new railway ballast. The willow-leaved sunflower also jumped fifty or sixty miles in the railroad ballast.

More cases of Senecio poisoning to cattle have come to light and a case of pokeweed poisoning horses. The latter case took place on the pasture of J. W. Bartholomew, near Morrill in Brown county, and resulted in the death of two horses with symptoms of colic followed by heart failure.

Among the unusual occurrences that might be mentioned were the following: A perfectly normal tree of *Carya ovata* (F. C. G. 16961) growing in Jackson county south of Birmingham had leaflets up to 26.5 cm. in length, instead of a maximum of 15 cm. allowed by manuals. Separation layers were imperfectly formed in a number of trees as usual in the fall of 1933, but perhaps the most unusual feature in this respect was that of coffee trees, *Gymnocladus dioica,* in Manhattan, in which, although the leaflets did fall off, the main and secondary axes of the leaves remained on a few trees until a snowstorm in late February, 1934, and in one tree were still present when the tree leaved out in May, 1934.

Work in adding to the collection of plants of Kansas during the past year resulted in the depositing of a collection of some 450 numbers of Osborne county plants by S. J. Neher and about 50 additional numbers from Saline county by John Hancin, in addition to occasional plants by others. At the

1. Contribution No. 348, Department of Botany, Kansas State College.

beginning of the year *Solanum rostratum* was represented in the state herbarium from 101 out of 105 counties. It has now been added from Crawford county by Clyde L. Merritt, from Norton county by myself, and from Hodgeman and finally Labette county in April, 1934, by E. G. Kelly, extension entomologist. This is the first case of the few plants which undoubtedly do grow in every county of the state having a complete 100 per cent representation in the state herbarium. During the year the Scrophulariaceæ of Kansas have been further checked by F. W. Pennell, of the Philadelphia Academy of Natural Sciences, the Equisetums checked and a paper on Kansas Equisetums written for publication by Prof. John H. Schaffner of the University of Ohio, and the genus *Juncus* has been completely worked up by F. J. Hermann, of University of Michigan, and a paper written for publication. Hermann's work has resulted in the adding of at least three species of *Juncus* to the state, which includes some very noticeable extensions of range. This is a group which is not usually noticed by the general public.

Among plants which appear to be new to the state are *Veronica persica* Poir from Saline and McPherson counties, *Eragrostis poœoides*, *Eragrostis barrelieri*, and *Sporobolus asper hookeri* from Saline county by John Hancin.

Assistance from student relief gave us a chance to bring the herbarium up to date in as far as the mounting of Kansas plants is concerned.

Study of Peridermium Gall on Western Yellow Pine

L. J. GIER, Will Mayfield College, Marble Hill, Mo.

The purpose of this study was to find the extent of this disease and some of the factors influencing its spread in order to promote more economical and efficient control measures.

The study was made in and around the Chadron State Park of Chadron, Nebraska, during June, July and August, 1933, while the writer was Camp Foreman of CCC Camp 102-S.

Chadron State Park is located near the extreme northwest corner of Nebraska at an elevation of about 4,500 feet and has an annual rainfall of 15 inches. This area is made up of extremely rugged cliffs and buttes with steep slopes and canyons. The soil is mainly a fine, sandy loam. The flood plains of the few streams are covered with some of the common hardwoods, but the hills are more or less clothed with a fine stand of Western Yellow Pine (*Pinus ponderosa*), among which are many trees that are over 200 years old.

Peridermium gall, pine gall or tree cancer is caused by an heterœcious rust. *Cronartium harknessii* Meinicke, or by an unidentified *Cronartium* (Hubert: Principles of Forest Pathology, 1931, page 255), whose alternate hosts are *Castilleja, Orthocarpus* and *Pedicularis* spp., none of which were found in this region during the period of this study. Hubert says it is now believed that this rust can readily reinfect the pine host by its æciospores, which must have been the case in this region.

On the pine, this rust forms more or less globose galls of corky tissue, encircling, or nearly encircling, the twig, several of which may be formed on a twig in a given year or they may form several galls successively down the twig or occasionally witches brooms will be formed. The galls are covered by the rough, scaly bark which splits to expose the masses of orange-colored æciospores following a shower or on cloudy days during the summer months. These orange-colored masses contrast strongly with the dark green of the foliage of the tree.

A survey was made to find (1) the percentage of trees infected, (2) the age of trees most commonly infected, and (3) the environmental factors that seemed to aid the infection. By walking through the forests one could quickly see the size trees which were most commonly infected. A number of these trees from different parts of the area were cut to determine the age. Representative plots were then selected in different parts of the area and 100 trees counted to determine the per cent of infection. The environmental factors exhibited here were noted. A total of about 30 plots was selected. These were taken from as nearly representative sections as possible, some being on east slopes, others on west, north or south, on steep slopes or gentle slopes, where crowded and where thin. These were then compared.

It was soon observed that the trees infected were the younger trees, mainly 15 to 25 years of age, although several were found up to 80 years of age that showed a few galls. The counts showed much the same results everywhere. The per cent infection ranged from 32 per cent to 82 per cent, with an average of 58.1 per cent of the trees infected. A slightly higher percentage occurred

on the southwest slopes than on other similar slopes with the lowest on the northeast. The highest percentages were found where the trees were most crowded, often as many as six trees per square foot being found.

From the absence of disease among the older trees one might conclude that the diseased trees were weaker and had died off in the struggle for existence. The limiting factor in the environment here was probably water, so the reason for the great amount of infection where the trees were thickest or on the southern slopes would be from weakening due to too xeric conditions. Thinning the trees appeared to be the simplest remedy. This, together with the destruction of diseased trees or branches, was the control measure employed.

The Flora of Osborne County, Kansas

S. J. NEHER, Portis, Kan.

Osborne county is situated in the north central part of Kansas, about 30 miles from the Nebraska line and about 170 miles east of the Colorado line. It has about 900 square miles, being thirty miles on each side. The first census, taken in June, 1871, showed 724 inhabitants, 281 of which were eligible to vote. The county was organized in the fall of 1871 and named after Vincent B. Osborne, a private of company A, Second Kansas cavalry.

The chief cultivated crops of Osborne county are wheat, corn, sorghums, and alfalfa. Beef and dairy cattle, hogs and poultry are the chief live stock. Considerable grazing is carried on over the hilly portions of the county. The annual average rainfall is about 20 inches, 80 per cent of which falls in the growing season.

Both the north and south branches of the Solomon river pass through the county. The former cuts through the northeast corner from Portis to Downs, while the latter passes through the entire county from west to east, passing near Alton and Osborne and thence eastward, uniting with the north fork a few miles east of the Osborne county line. A number of smaller streams flow northeastward into the South Solomon. These are Medicine creek, Kill creek (two branches), Covert creek, Indian creek, and other minor streams. The extreme southern portion of the county drains southward. All these streams have a fringe of trees. These are largely *Ulmus americana, Ulmus fulva, Populus sargentii, Salix amygdaloides* and *Quercus macrocarpa* interspersed with *Celtis occidentalis, Salix nigra,* and in some places *Juglans nigra.* In many of the swampy spots *Salix longifolia* is common. It is to be regretted that the few native trees in the county are being so rapidly cut down for fuel. However, it is gratifying to note that a number of low waste places are being planted to the elms and poplars.

The county as a whole is rolling to quite hilly. The highest elevation in the county is east of Covert and is about 2,000 feet above sea level. For the most part the hills are composed of limestone gravel, but in many places they are quite rocky. The characteristic flora of these hills are such plants as *Viorna fremontii, Polygala alba, Leucelene ericoides, Townsendia exscapa, Senecio plattensis, Tetraneuris fastigata,* and *Arenaria texana.* In most of the upland valleys the common trees are *Celtis occidentalis, Ulmus americana, Ulmus fulva* and *Quercus macrocarpa.* A few of the common shrubs in these valleys are *Rhus toxicodendron, Rhus trilobata* and *Ceanothus ovatus pubescens.*

A number of species of plants seem to be quite rare in the county. For instance, in my survey of the county for plants only one specimen of *Sonchus asper* was found. *Celastrus scandens* was found in but a few places and is confined to the wooded creeks or river banks. The small legume, *Acmispon americanus,* was found only in a certain pasture about three miles south of Downs. I found but two specimens of *Plantago lanceolata,* and these were near a small-town lawn. Two small mud-loving plants, *Cyperus inflexus* and *Heteranthera limosa,* were found only at the edge of a pond six miles northeast of

Natoma. *Typha latifolia* was found in but two places in the county, both being wet, marshy places near seepy ground or springs.

Some collections were made in Osborne county in the 1890's, principally by A. S. Hitchcock. These included about 100 species. The present collection includes 300 species and 77 families. The returns from some eight specimens of *Carex* and *Juncus* have not yet been received. I would estimate that there are at least 150 species of plants in the county that are not included in the present list, so there is still work to be done. Practically all of this list was collected in duplicate and a specimen of each one was sent to the botanical department of the Kansas State College at Manhattan to become a part of the state herbarium. I am keeping several other duplicates of each species for exchanging with any one interested.

In the classification of the plants in the present work I have followed Britton and Brown's "Illustrated Flora of the United States and Canada," 2d edition, with the exception of a few names which have of late come to have a better standing and a very few which are not described by Britton and Brown. I am very much indebted to Dr. F. C. Gates of the State College for his inspiration and untiring efforts in helping with the identification of the plants and in making suggestions as to how to proceed in working out the flora of the county.

The Flowering Plants of Osborne County, Kansas

The collections upon which this list is based were made during 1931-1932. For convenient reference I have arranged all families, genera, and species alphabetically, respectively.

Aceraceæ

Acer negundo

Aizoaceæ

Mollugo verticillata

Alismaceæ

Echinodorus cordifolius
Sagittaria ambigua
Sagittaria cuneata

Alsinaceæ

Arenaria texana

Amaranthaceæ

Amaranthus blitoides
Amaranthus graecizans
Amaranthus hybridus

Ammiaceæ

Cogswellia daucifolia
Cogswellia orientalis
Sanicula canadensis
Spermolepis patens

Anacardiaceæ

Rhus toxicodendron radicans
Rhus trilobata

Apocynaceæ

Apocynum sibiricum

Asclepiadaceæ

Acerates angustifolia
Acerates auriculata
Acerates viridiflora
Asclepias kansana
Asclepias latifolia
Asclepias pumila
Asclepias speciosa
Asclepias tuberosa
Asclepias verticillata
Asclepiodora viridis

Bignoniaceæ

Catalpa bignonioides

Boraginaceæ

Lappula texana
Lithospermum arvense
Lithospermum linearifolium
Onosmodium occidentale

Cactaceæ

Opuntia humifusa

CALLITRICHACEÆ

Callitriche palustris

CAMPANULACEÆ

Specularia leptocarpa
Specularia perfoliata

CANNABINACEÆ

Cannabis sativa

CAPPARIDACEÆ

Peritoma serrulata
Polanisia trachysperma

CAPRIFOLIACEÆ

Sambucus canadensis
Symphoricarpus occidentalis

CARYOPHYLLACEÆ

Saponaria officinalis
Silene antirrhina

CELASTRACEÆ

Celastrus scandens

CHENOPODIACEÆ

Chenopodium album
Chenopodium album viride
Chenopodium hybridum
Monolepis nuttalliana
Salsola pestifer

CICHORIACEÆ

Agoseris cuspidata
Lactuca pulchella
Lygodesmia juncea
Pyrrhopappus grandiflorus
Sonchus asper
Tragopogon pratensis

COMMELINACEÆ

Tradescantia bracteata
Tradescantia occidentalis

COMPOSITÆ

Achillea lanulosa
Antennaria campestris
Artemisia ludoviciana
Boebera papposa
Brickellia umbellata
Centaurea cyanus
Cirsium megacephalum
Cirsium undulatum

COMPOSITÆ—Concluded

Echinacea angustifolia
Eclipta alba
Erigeron canadensis
Erigeron ramosus
Gaillardia pulchella
Gnaphalium obtusifolium
Helianthus annuus
Helianthus maximiliani
Helianthus petiolaris
Hymenopappus scabiosaeus
Lepachys columnifera
Leucelene ericoides
Senecio integerrimus
Senecio plattensis
Sideranthus spinulosus
Silphium integrifolium
Silphium laciniatum
Solidago glaberrima
Tetraneuris fastigiata
Thelesperma gracile
Townsendia exscapa
Vernonia baldwinii

CONVOLVULACEÆ

Convolvulus americanus
Convolvulus arvensis
Convolvulus interior
Evolvulus nuttallianus

CORNACEÆ

Cornus asperifolia

CORRIGIOLACEÆ

Paronychia wardii

CRUCIFERÆ (BRASSICACEÆ)

Brassica nigra
Camelina microcarpa
Capsella bursa-pastoris
Cheirinia aspera
Cheirinia asperrima
Draba micrantha
Lepidium densiflorum
Lepidium virginicum
Lesquerella ovalifolia
Radicula sessiliflora
Radicula sinuata
Sisymbrium altissimum
Sophia brachycarpa
Sophia intermedia

CUCURBITACEÆ

Cyclanthera dissecta
Pepo foetidissima

CYPERACEÆ

Carex heliophila
Carex spp.
Cyperus filiculmis
Cyperus inflexus
Cyperus pallidus
Eleocharis acuminata
Eleocharis palustris
Scirpus americanus
Scirpus validus

EUPHORBIACEÆ

Croton texensis
Dichrophyllum marginatum
Poinsettia heterophylla
Tragia ramosa

FABACEÆ

Acmispon americanus
Amorpha canescens
Amorpha fragrans
Astragalus gracilis
Astragalus lotiflorus
Astragalus nebraskensis
Astragalus missouriensis
Astragalus plattensis
Glycyrhiza lepidota
Medicago sativa
Melilotus alba
Melilotus officinalis
Parosela aurea
Parosela enneandra
Petalostemon candidus
Petalostemon purpureus
Psoralea agrophylla
Psoralea cuspidata
Psoralea esculenta
Psoralea lanceolata
Psoralea tenuiflora
Robinia pseudoacacia
Sophora sericea
Strophostyles leiosperma
Trifolium repens
Vicia sparsifolia

FAGACEÆ

Quercus macrocarpa

FUMARIACEÆ

Corydalis micrantha
Corydalis montana

GROSSULARIACEÆ

Ribes missouriensis
Ribes odoratum

HYDROPHALACEÆ

Ellisia nyctalea

JUGLANDACEÆ

Juglans nigra

JUNCACEÆ

Juncus interior
Juncus torreyi

LAMIACEÆ

Hedeoma camporum
Hedeoma hispida
Leonurus cardiaca
Marrubium vulgare
Monarda mollis
Monarda pectinata
Nepeta cataria
Salvia lanceolata
Salvia pitcheri
Scutellaria resinosa
Teucrium canadense

LILACEÆ

Allium mutabile
Allium nuttallii
Smilacina racemosa
Smilacina stellata
Smilax hispida
Yucca glauca

LINACEÆ

Linum rigidum
Linum sulcatum

LOASACEÆ

Mentzelia oligosperma
Nuttallia decapetala

LYTHRACEÆ

Ammannia coccinea
Lythrum alatum

MALVACEÆ

Abutilon theophrasti
Althaea rosea
Callirrhoe involucrata
Hibiscus trionum
Malva rotundifolia
Sphaeralcea coccinea

MENISPERMACEÆ

Menispermum canadense

MIMOSACEÆ

Desmanthus illinoensis
Leptoglottis nuttallii

MORACEÆ

Maclura pomifera
Morus alba
Morus rubra

NYCTAGINACEÆ

Allionia linearis
Allionia nyctaginea

OENOTHERACEÆ

Gaura coccinea
Gaura parviflora
Oenothera fremontii
Oenothera missouriensis
Oenothera triloba
Oenothera serrulata
Oenothera speciosa
Stenosiphon linifolius

OLEACEÆ

Fraxinus pennsylvanica

OXALIDACEÆ

Oxalis stricta
Oxalis violacea

PAPAVERACEÆ

Argemone intermedia

PHYMACEÆ

Phryma leptostachya

PLANTAGINACEÆ

Plantago lanceolata
Plantago purshii
Plantago rhodosperma
Plantago rugelii

POACEÆ

Agropyron smithii
Andropogon furcatus
Bouteloua gracilis
Bromus inermis
Bromus japonicus
Bromus tectorum
Buchloe dactyloides
Cenchrus pauciflorus
Chloris verticillata
Digitaria sanguinalis
Distichlis stricta
Echinochloa crusgalli mitis
Eragrostis cilianensis
Eragrostis spectabilis
Festuca octoflora
Hordeum jubatum
Hordeum pusillum
Koeleria cristata
Panicum capillare
Panicum virgatum
Poa pratensis
Schedonnardus paniculatus
Setaria viridis
Sorghum sudanensis
Sporobolus cryptandrus

POLYGALACEÆ

Polygala alba
Polygala verticillata

POLYGONACEÆ

Polygonum buxiforme
Polygonum convolvulus
Polygonum lapathifolium
Polygonum neglectum
Polygonum pennsylvanicum
Polygonum persicaria
Polygonum tomentosum
Rumex altissimus
Rumex venosus

PONTEDERIACEÆ

Heteranthera limosa

PRIMULACEÆ

Androsace occidentalis

PRUNACEÆ

Prunus angustifolia watsonii
Prunus besseyi
Prunus cerasus
Prunus melanocarpa

RANUNCULACEÆ

Anemone caroliniana
Delphinium ajacis
Delphinium virescens
Ranunculus abortivus
Thalictrum hypoglaucum
Viorna fremontii

RHAMNACEÆ

Ceanothus ovatus pubescens

ROSACEÆ

Geum camporum
Rosa suffulta
Rubus occidentalis

RUBIACEÆ

Galium aparine
Houstonia angustifolia

SALICACEÆ

Populus sargentii
Salix amygdaloides
Salix longifolia
Salix nigra

SCROPHULARIACEÆ

Castilleja sessiliflora
Pentstemon cobaea
Scrophularia merilandica
Scrophularia occidentalis (?)
Verbascum thapsus
Veronica peregrina xalapensis

SOLANACEÆ

Physalis heterophylla
Physalis lanceolata
Physalis virginiana
Solanum carolinensis
Solanum interius
Solanum rostratum

TYPHACEÆ

Typha latifolia

ULMACEÆ

Celtis occidentalis
Ulmus americana
Ulmus fulva

URTICACEÆ

Parietaria pennsylvanica
Urtica procera

VERBENACEÆ

Phyla cuneifolia
Verbena bipinnatifida
Verbena stricta
Verbena urticifolia

VIOLACEÆ

Calceolaria verticillata
Viola nuttalli
Viola papilionacea
Viola rafinesquii

VITACEÆ

Psedera quinquefolia
Vitis vulpina

ZANNICHELLIACEÆ

Potamogeton americanus
Potamogeton foliosus

ZYGOPHYLLACEÆ

Tribulus terrestris

Noteworthy Anatomical Features from the Wood of Some Indigenous Kansas Shrubs and Lianas

D. J. OBEE, University of Kansas, Lawrence, Kan.

(PLATE I)

Following a softening procedure, cross, longitudinal radial and tangential sections were cut from the wood of 16 shrubs and 4 lianas indigenous to Kansas, some of which, as *Euonymus atropurpureus* and *Staphylea trifoliata*, reach tree proportions. It is the purpose of this paper to deal with only two aspects of the anatomical features, namely, the percentage of the wood occupied by the different tissues, and the frequencies and extent of contact of the rays with the tracheal tubes.

The percentage of the wood occupied by the various tissues was ascertained first by identifying the tissues present through examination of a series of cross and longitudinal sections of each species. In some instances macerations were made in an effort to detect the presence of isolated tracheids or xylem parenchyma cells. Having thus identified the tissues present, the percentage occupied by each was computed by examining a number of cross sections and measuring the areas occupied by each of the tissues and then calculating the percentages for each species. Precautions were taken to have these calculations made from sections showing complete rings of growth in the field of the microscope, because, in the case of the tracheal tubes especially, the percentage occupied is in most species considerably higher in the early than the late growth. These figures are compiled in tabular form in Table 1.

The average percentage of the wood occupied by the different tissues in these 20 species is as follows: tracheal tubes 32 per cent, xylem rays 16.5 per cent, xylem parenchyma 2.6 per cent, wood fibers 34 per cent, tracheids 15 per cent, and fiber-tracheids 36 per cent. In the case of the wood fibers, tracheids and fiber-tracheids, these figures represent the average for those species in whose wood these tissues were found.

Remembering that tracheal tubes are employed for the longitudinal ascent of water and mineral salts in solution, the xylem rays for storage and radial transmission of water and food, xylem parenchyma for storage, wood fibers for strength, and tracheids and fiber-tracheids both for water conducting and strengthening, it is evident that the wood of these indigenous shrubs and lianas is devoted chiefly to water-conduction and strengthening with a smaller percentage devoted to storage in the form of xylem rays and xylem parenchyma. However, exceptions to this situation were found in *Vitis cordifolia* and *Psedera quinquefolia*, two high-climbing lianas, in which a higher percentage of the wood is devoted to storage than to strengthening, and the percentage occupied by the unusually large tracheal tubes is much higher than the average for these 20 species. Compare figure 1 showing a photomicrograph of a cross section of *Vitis cordifolia* wood with figure 2, a cross section of the wood of *Sambucus canadensis*, which is representative of the shrubs examined. These lianas do not have to depend on their strengthening tissues alone for support,

TABLE 1.—Percentage of the wood occupied by the various tissues

	Tracheal tubes.	Xylem rays.	Xylem paren-chyma.	Wood fibers.	Tra-cheids.	Fiber tra-cheids.
1. Amorpha fragrans	16	22	4	19	....	39
2. Æsculus glabra arguta	33	15	2	39	....	11
3. Cephalanthus occidentalis	25	16	4	6	....	49
4. Tecoma radicans	24	10	1	13	....	52
5. Ceanothus americanus	32	13	....	53	2	....
6. Prunus virginiana	39	7	....	....	....	54
7. Staphylea trifoliata	25	18	3	3	....	51
8. Sambucus canadensis	30	18	2	....	28	22
9. Euonymus atropurpureus	58	16	1	....	....	
10. Zanthoxylum americanum	29	16	5	50	....	....
11. Celastrus scandens	54	18	3	....	....	25
12. Ribes missouriense	40	19	2	8	....	31
13. Corylus americana	28	16	3	53	....	....
14. Rhamnus lanceolata	22	16	2	22	....	38
15. Symphoricarpos orbiculatus	34	12	3	51	....	....
16. Rosa setigera	21	18	1	60	....	....
17. Vitis cordifolia	50	35	4	11	....	....
18. Psedera quinquefolia	60	20	1	19	....	....
19. Rhus glabra	20	12	2	66	....	....
20. Cornus asperifolia	17	13	5	65	....	....

and the water and mineral salts in solution must sometimes be carried for great distances to reach the leaves. Therefore, the possession of these large tracheal tubes to the partial exclusion of strengthening tissues appears to be a very rational adjustment to the needs of these high-climbing plants.

The xylem rays of these lianas are also quite distinctive because of their relatively high vertical extent and wide tangential diameters. As revealed in cross and longitudinal tangential sections, these rays are up to 12 cells wide in their tangential diameter in *Vitis cordifolia* (Fig. 1), while in the shrubs examined the rays were never more than four cells wide and in a decided majority of the species the rays were only one cell wide in their tangential diameters. This contrast is evident in comparing figures 1, 3, and 4, in which the width of the rays of *Vitis cordifolia* can be compared with those of *Staphyles trifoliate* and *Sambucus canadensis,* two representatives of the shrubs examined.

The correlation of large tubes with the large rays is necessary because the large water tubes would stand in the way of many small rays cutting across. Fewer large rays meet the situation much better (Fig. 1).

Considering the tracheal tubes, it is seen that these tissues occupy from 16 per cent of the wood in *Amorpha fragrans* to 60 per cent in *Psedera quinque-*

folia. Note that the percentage of tracheal tube area in the 3 lianas, *Vitis cordifolia, Psedera quinquefolia,* and *Celastrus scandens,* which have relatively large tracheal tubes, is much higher than in most of the shrubs. However, *Euonymus atropurpureus* is an exception among the shrubs in its equalling the lianas in the percentage of its wood occupied by tracheal tubes which, although unusually small, are of such frequency as to accomplish this result. *Tecoma radicans* appears to be an exception among the lianas by having a lower percentage of its wood occupied by the tracheal tubes than average, although it has a high percentage of fiber-tracheids, which serve both for water conduction and strength.

With respect to the percentage of wood occupied by the rays and xylem parenchyma, there is less variation than noted with the other tissues. Three species, *Tecoma radicans, Prunus virginiana* and *Ceanothus americanus,* are noteworthy in having a lower percentage of wood occupied by xylem rays. In the sections of the latter two species no xylem parenchyma cells were found.

Thus, it is very apparent that these species have low-storage capacity in comparison with the other species examined, at least in the wood of the stem. How this low-storage percentage is recompensed was worked out in the case of *Ceanothus americanus.* It is known that this shrub has a well-developed underground system, and sections from the wood there showed numerous rays with large cells (44 per sq. mm. as seen in longitudinal tangential sections, occupying 38 per cent of the wood). This is more than double the average found in the wood of the above-ground stems of the 20 species.

There is considerable variation in the percentage of wood occupied by wood fibers and fiber-tracheids, ranging from complete absence of one or the other in some species to over 50 per cent of the wood being composed of one or both of these two tissues. It is significant that in those species with no wood fibers at all, or a low percentage, there is a correspondingly high percentage of the wood occupied by fiber-tracheids. This is outstanding in *Cephalanthus occidentalis, Tecoma radicans, Staphylea trifoliata* and *Ribes missouriense.*

It is striking that of the species examined only two possessed tracheids, and of these *Sambucus canadensis* was the only species with a high percentage (Fig. 3). However, over half of the species studied had fiber-tracheids which were capable both of giving strength and carrying on conduction.

It is quite apparent that the wood of those species with fiber-tracheids in addition to a high percentage of tracheal tube area, as in *Euonymus atropurpureus, Ribes missouriense, Prunus virginiana, Staphylea trifoliata,* and *Aesculus glabra arguta,* is largely given over to water conduction. In the case of *Amorpha fragrans, Cephalanthus occidentalis, Rhamnus lanceolata,* and *Tecoma radicans,* whose percentage of wood composed of tracheal tubes is below the average, the possession of fiber-tracheids is of significance and represents a fortunate adjustment for these species.

By study of a series of longitudinal tangential sections of each species the frequency of xylem rays per sq. mm., number of rays in contact per cm. of the length of the tracheal tubes, and percentage of the tube radial wall in contact with the rays were ascertained. These figures are given in table 2. *Staphylea trifoliata* approaches very close to the average found for the 20

species in all these respects and a photomicrograph of a longitudinal tangential section of the wood of this shrub is included. (Fig. 4.)

TABLE 2.—*Frequency of rays and their contact with the tracheal tubes*

	Number rays per sq. mm.	Number rays in contact per cm. of tube length.	Percentage of tube radical wall in contact with rays.
1. Amorpha fragrans	19	39	28
2. Æsculus glabra arguta	40	50	28
3. Cephalanthus occidentalis	35	30	45
4. Tecoma radicans	20	38	25
5. Ceanothus americanus	29	42	65
6. Prunus virginiana	21	28	25
7. Staphylea trifoliata	29	36	40
8. Sambucus canadensis	12	22	50
9. Euonymus atropurpureus	28	35	30
10. Zanthoxylum americanum	20	30	30
11. Celastrus scandens	22	12	60
12. Ribes missouriense*	8	11	24
13. Corylus americana	26	30	45
14. Rhamnus lanceolata	23	24	38
15. Symphoricarpos orbiculatus	24	8	30
16. Rosa setigera	23	10	50
17. Vitis cordifolia*	2	6	66
18. Psedera quinquefolia	3	8	75
19. Rhus glabra	21	34	40
20. Cornus asperifolia	19	18	32

* Rays for the most part separated from the tubes by thin-walled xylem parenchyma or fiber tracheids.

In those species in which the rays are small, both in tangential diameter and vertical extent, as in *Aesculus glabra arguta* and *Cephalanthus occidentalis,* the rays are more numerous than in *Vitis cordifolia, Psedera quinquefolia* and *Ribes missouriense,* which have large rays. The average number of rays per sq. mm. for these 20 species was 27.5. The number of rays in contact per centimeter of the vertical length of the tracheal tubes, as seen in longitudinal tangential sections, averaged 25, varying from 6 in *Vitis cordifolia,* whose rays are wide and have a high vertical extent, to 50 in *Aesculus glabra arguta,* a shrub with small rays of a low vertical extent. In *Ribes missouriense* and *Vitis cordifolia* the rays are rarely directly in contact with the sides of the tracheal tubes, being separated from the latter either by a layer of thin-walled xylem parenchyma cells or fiber tracheids. The percentage of tube radial wall in contact with the rays was fairly uniform and averaged 41 per cent for the 20 species. In this respect three out of the four lianas examined: *Vitis cordi-*

folia, Psedera quinquefolia, and *Celastrus scandens,* are considerably above the average, while *Tecoma radicans* is below the average. In this respect it conforms more to the situation found in most of the shrubs. A few of the shrubs, as *Ceanothus americanus, Sambucus canadensis* and *Rosa setigera,* were above the average, and equaled the lianas named above in the high percentage of the sides of their tubes in contact with the rays as seen in longitudinal tangential sections.

PLATE I

(Photomicrographs)

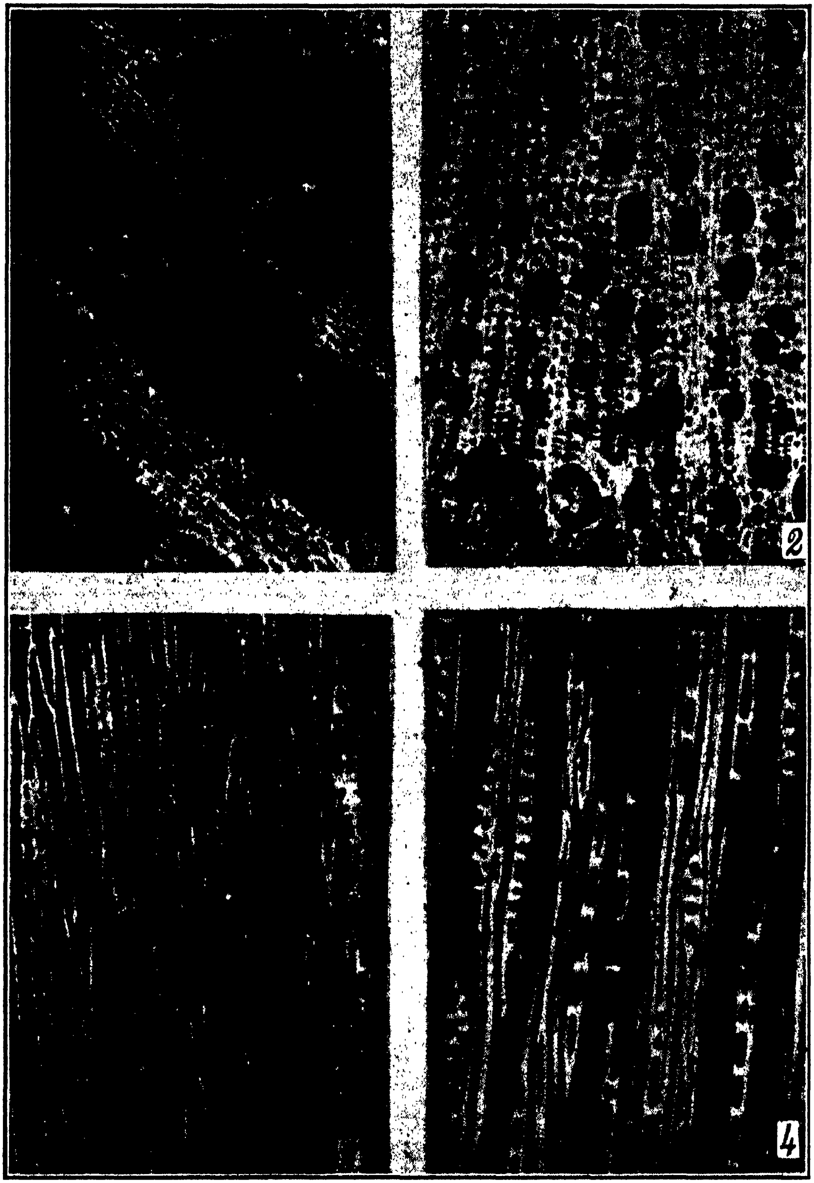
FIG. 1. A cross section of the wood of *Vitis cordifolia*. $\times$ 90

FIG. 2. A cross section of the wood of *Sambucus canadensis*. $\times$ 150.

FIG. 3. A longitudinal tangential section of the wood of *Sambucus canadensis*. $\times$ 150.

FIG. 4. A longitudinal tangential section of the wood of *Staphylea trifoliata*. $\times$ 150.

PLATE I



Köjic Acid—A Review

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I. DISCOVERY

Köjic acid was first isolated by Dr. K. Saito (*1*) from *Aspergillus oryzæ* grown on steamed rice. The compound was extracted from the finely powdered fungus with hot water. This was then extracted with ether, yielding the crude product, which was purified by recrystallization from hot water. He obtained köjic acid in the form of colorless needles and observed that its aqueous solution gave an intense red coloration with ferric chloride. Qualitative tests showed that it was not oxalic, succinic, citric, malic, tartaric, or benzoic acid which frequently occur in the lower fungi. However, because of its melting point and its behavior with ferric chloride he supposed it to be β-resorcyl-carbonic acid.

Because of the difficulty of obtaining the compound in sufficient quantities he did not continue its study. T. Yabuta (*2, 3, 4, 5*) became sufficiently interested in it to undertake the preparation of numerous derivatives from it, and, from these studies, established its structure. It was Yabuta who named the compound Köjic acid, probably because of its origin and its acidic nature.

A few years later, F. Traeta-Mosca (*6*), while investigating the fermentation of fructose and sucrose with A. glaucus, isolated a compound which he at first believed to be the γ-lactone of trihydroxy hexadiene acid.

Later (*7*) he observed the formation of the same compound during the fermentation of glycerol by the same mold. The chemistry of it was further studied and the conclusion that it was a hydroxymethyl hydroxy γ-pyrone arrived at. A comparison of the chemical behavior of Yabuta's köjic acid with that of Traeta-Mosca's γ-lactone of trihydroxy hexadiene acid appears to indicate that the two substances are identical. A comparison of some of the properties observed by these investigators is shown on page 92.

II. CONSTITUTION

T. Yabuta (*2*) began his investigation of köjic acid by the accumulation of a fairly large quantity of the pure compound. His analysis of it confirmed the empirical formula—$C_{12}H_{14}O_8$—obtained by Saito (*4*). From the fact that it formed (a) a copper salt and (b) acetyl and benzoyl derivatives, he concluded that the molecule had two carboxyl groups and four hydroxyl groups and could be written $C_{10}H_8(OH)_4(COOH)_2$. This was contrary to the opinion of Saito (*1*) that it was β-resorcyl carbonic acid.

Later, when T. Yabuta (*3*) determined its molecular weight, he found that the molecular weight of his first formula was almost exactly double its real value. Moreover, the intense red coloration (1:200,000) with ferric chloride, and its precipitation from concentrated solutions of its sodium salt by carbon dioxide, indicated that the ability of köjic acid to form salts, such as those of sodium, copper, barium, and lead, was due to a nuclear hydroxyl group. That he could prepare diacetyl, monobenzoyl, dibenzoyl, phenylcarbamate, and dimethyl derivatives of köjic acid meant the presence of two hydroxyl groups.

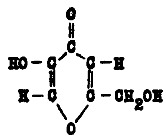
γ-lactone, m.p. 154°C.

1. Turns violet in light.
2. Very soluble in H_2O, EtOH, AcMe.
   Less soluble in EtOH-$(Et)_2O$, Et_2O.
   Insoluble in C_6H_6, $HCCl_3$.
3. Forms $(C_6H_5O_4)_2$ Cu.H_2O.
4. Bromine compound, m.p. 199°C.
5. Forms $C_6H_5O_3$ (OMe), m.p. 165°C, which gives no color with $FeCl_3$.
6. $C_6H_5O_3(OMe) + CaO$ or $Ba(OH)_2$ in 1200 cc. H_2O gives distillate with fruity odor, reduces Fehling's solution, AgOH, and gives HCI_3 reaction.
7. $C_6H_5O_3(OMe) + NH_4OH$ for 3 hours on H_2O bath gives crystals from EtOH m.p. 95°C.
8. Oxidized by $KMnO_4$.

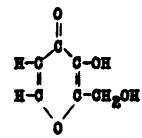
Köjic acid, m.p. 152°C.

1. Not observed.
2. Readily soluble in H_2O, EtOH, EtOAc.
   Less soluble in Et_2O, $HCCl_3$, C_5H_5N.
   Scarcely at all in other solvents.
3. Forms $(C_6H_5O_4)_2$ Cu.H_2O.
4. Mono-brom derivative m.p. 159°-160°C.
5. Forms $(C_6H_5O_3)$ OMe m.p. 160°-161°C.
   No color with $FeCl_3$.
6. $C_6H_4O_2(OMe)_2 +$ boiling $Ba(OH)_2$ solution gives equimol. proportions of HCOOH, CH_3OCH_2COOH and $CH_3OCH_2COCH_3$.
7. $C_6H_5O_3(OMe) + NH_4OH$ at 100°C. in sealed tube gives compound m.p. 111°-112°C.
8. Oxidized by $KMnO_4$.

When he treated the dimethyl ether of köjic acid with ammonium hydroxide he obtained a product with the empirical formula $C_8H_{11}O_3N$—probably the dimethyl ether of a hydroxy methyl hydroxy pyridone—which reaction he believed to be suggestive of a γ-pyrone. As a consequence of the above behavior it appeared that köjic acid must have either of the two following constitutional formulæ:

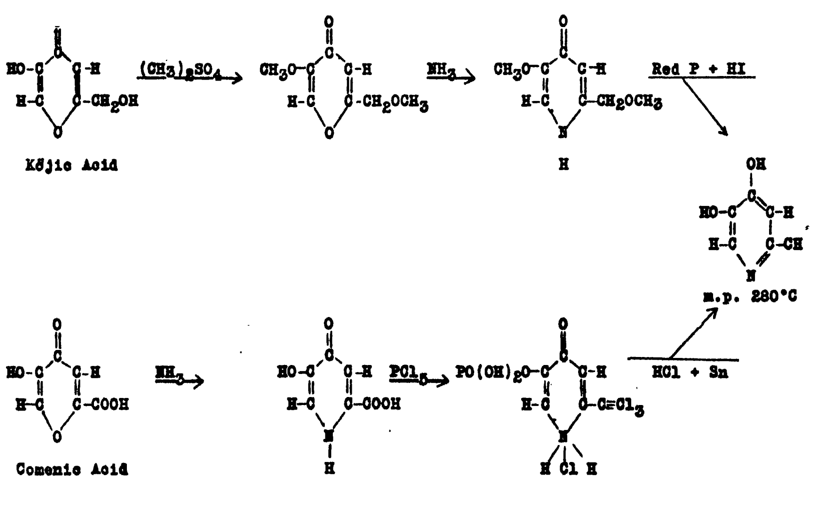


(1)



(2)

Yabuta used the reaction of köjic acid with diazobenzene acetate in deciding between the above formulæ as had Peratoner and Tamburello (*8*) in the study of maltol, 2-methyl-3-hydroxy-γ-pyrone, and Peratoner and Pelazzo (*9*) who assigned to comenic acid a structure similar to formula 1 because it does react with diazobenzene acetate, while maltol does not. Since formula 1 can furnish tautomerically the group -CO-CH_2-, which is necessary for reaction with diazonium salts and formula 2 does not, and since köjic acid does react with diazonium salts, Yabuta concluded that the constitution of köjic acid is expressed by formula 1. His efforts to confirm this conclusion by converting köjic acid into known pyrone and pyridone compounds by oxidation and reduction methods were not successful because of the instability of the pyrone nucleus. If comenic acid could be obtained by the direct oxidation of köjic acid, little doubt would remain as to the correctness of formula 1 and, although this was not found possible, Yabuta (*4*) did succeed in converting köjic acid and comenic acid into the same 4-5-dihydroxy-2-methyl pyridine. Below are given the probable equations for the preparation of this derivative:



The method according to which the 4-5-dihydroxy-2-methyl pyridine is prepared from comenic acid was developed by Ost (*10*). The high melting point of the dihydroxy picoline, 280°C., made it unsuitable for a mixed melting point. For this reason picolines from both sources were methylated with dimethyl sulfate, giving products which, either singly or mixed, melted at 98°C.

The above reactions may be considered as proof of the relationship between köjic acid and comenic acid.

In a still later publication Yabuta (*5*) reported that he had been successful in oxidizing the methyl ether of köjic acid to the methyl ether of comenic acid and the methyl ether of comenamic alcohol to the methyl ether of comenamic acid.

Armit and Noland (*11*) quite independently were successful in the oxidation of 5-methoxy-2-hydroxy methyl-γ-pyridone to the methyl ether of comenamic acid by means of nitric acid.

These direct oxidation reactions carried out by Yabuta and Armit and Nolan afford direct and convincing proof of the accuracy of Yubuta's formula for köjic acid.

III. RECOVERY AND QUANTITATIVE ESTIMATION

In the recovery of sufficient köjic acid for his use Yabuta (*2*) extracted köji with alcohol, evaporated to dryness, took the residue up with water, and precipitated with basic lead acetate. The precipitate thus formed was filtered off and hydrogen sulfide passed into the filtrate to remove excess lead, after which the solution was heated in vacuo to remove the hydrogen sulfide. The acid solution was neutralized with sodium hydroxide and copper sulfate solution was added with the immediate precipitation of copper köjate. The practical insolubility of copper köjate makes the separation of köjic acid quantitative. After washing the salt with water, it was decomposed with hydrogen sulfide, the copper sulfide filtered off, and the excess hydrogen sulfide removed by evaporation. Köjic acid crystallizes out when the volume becomes sufficiently small and may be further purified by fractional crystallization. It has been found by others (*12*) who have attempted its recovery in this way that there is difficulty in precipitating the copper sulfide in such a condition that it filters readily; moreover, the discoloration of the product is increased. In those fermentations where nearly all the sugar has been consumed, it is a simple matter to recover almost all the köjic acid as a pure product by merely concentrating its solutions isothermally with subsequent recrystallizations and finally decolorization with charcoal. The final product is perfectly white and has a melting-point range of less than a degree.

A number of methods have been suggested and used for the quantitative estimation of köjic acid, the merits of which will vary according to the quantities of the compound present and the nature of the investigation. Tamiya (*13*) and Corbellini and Gregorini (*14*) made use of the intense red coloration produced by the action of ferric chloride on köjic acid in its estimation colorimetrically. Challenger, Klein, and Walker (*15*) repeatedly extracted the culture media and washings with ether and weighed the product. May, Moyer, Wells and Herrick (*16*) precipitated the köjic acid as the copper salt with N/10 copper acetate and weighed it as $Cu(C_6H_5O_4)\,2.\tfrac{1}{2}\,H_2O$. They pointed out also that, in the absence of other acids, köjic acid could be determined

accurately by titration with dilute alkali with alizarin orange R as the indicator. However, the yellow color of the culture solutions interfered with the end point. Others (*12*) have found the weighing of köjic acid as $Cu(C_6H_5O_4)$ $2.\frac{1}{2}\ H_2O$ to be entirely suitable for its estimation. Titration with dilute alkali with phenolphthalein as the indicator to full red color served almost as well, particularly when the titrations were made over a source of diffused light. The volumetric method checks well with the gravimetric method except, perhaps, at high concentrations, where it gives slightly higher values. In fermentation experiments, where variations between cultures are likely to be relatively large, köjic acid may be determined rapidly and with sufficient accuracy volumetrically. Birkinshaw and Raistrick (*17*), while using the iodine absorption method of Hinton and Macara (*18*) for the estimation of residual glucose, noticed that an immediate turbidity and a strong odor of iodoform resulted after the addition of iodine and sodium hydroxide to the culture medium. It was found that köjic acid was responsible for these results, which led to an investigation of the products of the reactions and the mechanism of the reactions which occur. The outcome of the study was the development of a method for the quantitative estimation of köjic acid, even in the presence of glucose, provided the analysis for glucose is made independently. The course of the reaction was summarized as follows:

$$(1)\quad C_6H_6O_4 + 2H_2O \longrightarrow HCOOH + CH_3COCH_2OH + \begin{matrix} CHO \\ | \\ CHO \end{matrix}$$

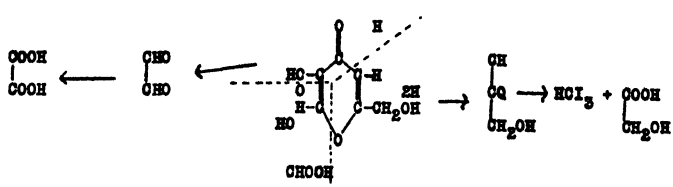
$$(2)\quad HCOOH + NaOH \longrightarrow HCOONa + H_2O$$

$$(3)\quad CH_3COCH_2OH + 3I_2 + 4NaOH \rightarrow HCI_3 + \begin{matrix} CH_2OH \\ | \\ COONa \end{matrix} + 3NaI + 3H_2O$$

$$(4)\quad \begin{matrix} CHO \\ | \\ CHO \end{matrix} + 2I_2 + 6NaOH \longrightarrow \begin{matrix} COONa \\ | \\ COONa \end{matrix} + 4NaI + 4H_2O$$

$$C_6H_6O_4 + 5I_2 + 11NaOH \longrightarrow HCI_3 + 7NaI + HCOONa + 6H_2O + \begin{matrix} COONa \\ | \\ COONa \end{matrix} + \begin{matrix} CH_2OH \\ | \\ COONa \end{matrix}$$

They are of the opinion that the mechanism of the breakdown of the köjic acid may be expressed by the following scheme:



In order that accurate analyses may be made, it is necessary that four times the theoretical quantity of iodine be used, and at least 90 minutes be allowed for completion of the reaction.

IV. FORMATION

The only way in which köjic acid has been prepared in any quantities is by fermentation. Numerous carbon sources such as polysaccharides, disaccharides, hexoses, pentoses, sugar alcohols and organic acids have been used in its formation with varying success. Of these, glucose and xylose have been studied the most extensively and the greatest yields have been obtained from them. With the exception of ten species of acetic acid bacilli (*19*) and a single penicillium (*20*), *P. daleæ,* köjic acid has been found only in cultures of the *Aspergilli.* The ability to produce köjic acid is developed to a high degree in the *A. oryzæ-flavus* group. According to Yabuta's (*2*) observations the varieties of *A. oryzæ* isolated from "Tamari-köji" produced more acid than those isolated from "shoyu" or "Sake-köji." He found, also, that generally those which liquefy gelatin to a greater degree seem to produce more acid. Raistrick states that the ability of Aspergilli to produce köjic acid may be utilized as a diagnostic test for members of the *A. oryzæ-flavus-tamarii* group, particularly if certain definite cultural conditions are employed. Yabuta (*2*) observed that *A. albus, A. candidus,* and *A. nidulans* produced köjic acid, which was noted also by Challenger (*21*). Raistrick assumed that the inconsistency between Yabuta's and his results was due to different cultural conditions, and gives some evidence that Traeta-Mosca (*6*), who claimed that he had used *A. glaucus* to produce köjic acid, had in reality used a member of the *A. flavus-oryzæ* group. There is some reason to believe also that *A. niger* is capable at times of the production of köjic acid, since Sauton (*22*) and Javillier and Sauton (*23*) have observed the formation of a red color when ferric chloride was added to cultures of *A. niger* on Rawlin's sugar medium. It appears, therefore, that the diagnostic value of köjic acid formation is somewhat doubtful, in view of the variety of conditions under which it is formed.

The concentrations of the carbon source used in those experiments in which the köjic acid formed was quantitatively determined have varied between rather wide limits—five to thirty per cent. In some of the recent investigations the carbon source has been varied in order to find the concentrations giving the best yields. Herrick (*16*) found 20 per cent to be optimum for commercial dextrose (1-molal) when fermented with *A. flavus.* For xylose (*12*), when fermented by *A. flavus,* a concentration of 15 per cent (1-molal) was found to be best. The choice of a carbon source must depend in a large measure upon the organism employed. Raistrick (*20*) found that sucrose, among a number of other carbon sources, gave the best yield with *A. parasiticus,* while Herrick (*16*) obtained high yields by fermenting glucose with *A. flavus.* Others (*12*) have fermented both xylose and glucose with an *A. flavus* and, up to the present time, glucose has outyielded xylose to some extent; however, the results are not exactly comparable. Challenger (*15*), when fermenting a 10 per cent solution of arabinose, xylose, and glucose with an *A. oryzæ,* obtained the best yields from xylose, while Katagiri (*24*), also working with an *A. oryzæ* on 5 per cent solutions of rather a large number of sugars and other compounds, found glucose to be the best. These last two cases, however, may not be significant, as the cultural conditions were not identical.

Several sources of inorganic nitrogen have been used, such as NH_4NO_3,

$NaNO_3$, $(NH_4)_2SO_4$, $(NH_4)_2HPO_4$, and $(Co(NH_3)_5.H_2O)Cl_3$. In most cases, NH_4NO_3 proved to be the most satisfactory (*15, 13, 16, 12, 20*). Tamiya (*13*) noted that the NH_4 is consumed more rapidly than the NO_3, the NO_3 beginning to be used at the pH 3.4 with corresponding reduction of acidity. Other (*12*) results have shown that the concentration of NH_4NO_3 should be kept as low as the growth of the organism will permit, which is in agreement with the findings of Currie (*25*) in his study of citric acid formation by *A. niger*. Kinoshita's (*26*) observation that köjic acid production was increased when cobalt ammine salts are used as sources of nitrogen likewise shows this to be the case, although Challenger (*15*), who also used a cobalt ammine salt in a single experiment, did not observe that it had any advantage over NH_4NO_3. Phosphate and magnesium requirements from the standpoint of yields have received less attention than other nutrients. However, (*12*) in the fermentation of xylose solutions with an *A. flavus*, the variation of phosphate shows two apparent maxima, the lower concentration favoring a greater yield. It was found, also, that after a certain minimum concentration of $MgSO_4.7H_2O$ is reached, an increase has little effect.

When reference is made to the pH suitable for köjic acid production, it should be to the pH prevailing in the medium at the time of inoculation, since it has been found (*13, 27, 12*) that it increases slightly and gradually with the progress of fermentation, after an initial precipitate drop over a short-time interval (*12*). When phosphate concentrations are relatively high, the increase in pH is greater. Investigators are not in agreement as to what the initial pH should be. It (*12*) has been found that, in the fermentation of xylose with an *A. flavus*, the initial pH should be as low as the organism will tolerate, which will depend to some extent upon the degree to which a single variety is acclimated to acid conditions. In these experiments, the initial pH has varied between 2.5 and 3.5. Katagiri (*24*) using an *A. oryzæ*, found that, although the optimum pH for mold growth was about 5.0, the optimum pH for köjic acid formation was 2.4. Tamiya's observations (*13*) were very interesting in this connection. The pH range for mold growth was found to be between 2.1 and 8.6 with maxima at 3.5 and 7.0. At the minimum, 5.5, between the maxima 3.5 and 7.0, the köjic acid formation was the greatest. Perhaps this phenomenon may be correlated with the effect of phosphate variation (*12*) and the observation (*28*) that the köjic acid production-time curves vary periodically with different temperatures of autoclaving of the medium. It is possible to account for the maxima in the three cases by assuming that the availability of phosphorus has varied, which would have a direct bearing on pH recovery during fermentation.

The temperatures employed by different investigators also vary considerably. Sakaguchi (*27*), fermenting glucose with an *A. oryzæ*, found that different temperature ranges determined to some extent whether köjic acid or citric acid formation would predominate, and that köjic acid was markedly produced at 15° to 20° C. Raistrick (*20*) fermented glucose and sucrose solutions with an *A. oryzæ* over a time interval of from four to six weeks at a temperature of 23°-25° C. Herrick (*16*) obtained excellent yields of köjic acid from glucose when fermenting its solutions with an *A. flavus* at 35° C. and the results show that one of the effects of increased temperature is, within limits, to decrease

the time required for completion of fermentation. Others also have obtained (*12*) good yields when fermenting xylose and glucose solutions with an *A. flavus* at 35° C. and have further increased yields from glucose by culturing for about the first five days at 35° and thereafter at room temperature—23°-25° C. This last effect is interesting in view of the fact that some recommend low temperatures for köjic acid formation.

If fermentation methods are to be used for the production of köjic acid in quantity, the time element is important. Although the yields obtained by Raistrick (*20*), 17-19 per cent, are good, the period of four to six weeks, which was required, would make the process an expensive one. Herrick's (*16*) results show that 45 per cent of the glucose present can be converted into köjic acid in a period of 12 days, while others have done as well (*12*) in 9 days.

In Table I is given a comparison of the media employed, time intervals, temperatures, and yields obtained by several investigators:

TABLE I

Investigators	(12) Smits and Barham		(16) May and Herrick		Birkinshaw and Raistrick (20)	
Organism	A. flavus		A. flavus		A. parasiticus	
Media (grams/liter)	xylose or glucose	150.0 183.0	glucose	183.0	glucose or sucrose	50.0 50.0
	NH_4NO_3	1.0	NH_4NO_3	1.125	$NaNO_3$	2.0
	KH_2PO_4	0.625	H_3PO_4	0.054	KH_2PO_4	1.0
	$MgSO_4 \cdot 7H_2O$	0.50	$MgSO_4 \cdot 7H_2O$	0.50	$MgSO_4 \cdot 7H_2O$ $FeSO_4 \cdot 7H_2O$	0.50 0.01
	H_2SO_4	0.78	KCl	0.10	KCl	0.50
Temperatures	35°C 35°C and 23°-25°C		35°C		23°C-25°C	
Time-intervals	16 days 9 days		12 days		4 weeks	
Yield Köjic Acid (weight/weight)	36% 37%-41%		38%		16.8% 18.8%	

Investigators	Challenger (15)		Katagiri (24)		Sakaguchi (27)	
Organism	A. oryzae		A. oryzae		A. oryzae	
Media (grams/liter)	xylose or glucose	100.0 100.0	glucose	50.0	glucose	100.0
	NH_4NO_3	0.4	$(NH_4)_2SO_4$	0.5	peptone	6.0
	KH_2PO_4	1.0	KH_2PO_4	1.0	KH_2PO_4	0.15
					K_2HPO_4	0.15
	$MgSO_4 \cdot 7H_2O$	0.1	$MgSO_4$	0.1	$MgSO_4$	0.1
			$CaCl_2$	0.1	$CaCl_2$	0.1
					NaCl	Trace
					$FeCl_3$	Trace
Temperatures	31°C-32°C		15°C-18°C		---	
Time-intervals	7 days		---		---	
Yield Köjic Acid (wt/wt)	5.0% 3.8%		---		---	

There has been some effort made to increase the yield of köjic acid through the use of inorganic and organic accelerators. The following salts (*12*), $Fe(NH_4)_2(SO_4)_2.6H_2O$, $CoCl_3$, $CuCl_2$, $NiCl_2$, $ZnSO_4.7H_2O$, $Al_2(SO_4)_3.18 H_2O$, $MnSO_4.7H_2O$, and $Ca(OAc)_2.H_2O$, have been added in concentrations of from 1 to 2 parts per million to *A. flavus* fermenting media and some evidence has been found that additions of Ca and Al tend to increase, Co and Cu to decrease, and the others to be without effect upon yields obtained. According to Tamiya (*13*) certain free organic acids inhibit growth of *A. oryzæ,* while their salts accelerate growth. Köjic acid formation is rapidly reduced by the addition of oxalic, citric and formic acids. HCl and HNO_3 also decreased its production, while H_2SO_4 slightly increased it. When tartaric acid was added at a low pH and when H_3PO_4, lactic, and pyruvic acids are added at the iso-electric point of the protein (pH 5-6) production is increased. Herrick and coworkers (*29*) have tested forty compounds and found only one of them to have a marked accelerating effect. 0.10 gm. of ethylene chlorhydrin per liter brought a decided increase in yield of köjic acid during a ten-day interval. Of the remainder, thiourea, thioglycolic acid, sodium thiocyanate, chloroacetone and ortho and para chlorophenols were markedly inhibitory.

Table II is a compilation of the organic substances which have either been fermented to köjic acid (+) or have been used in the attempt to form köjic acid from them (—) with negative results. In one part of the table, the C-sources are listed alphabetically with the organism used to ferment them, while in the other part the organisms are listed alphabetically with the C-sources upon which they have been grown. In each case the reference is also given.

TABLE II.

C—source	+ —	Organism	Reference
acids (amino)	—	A. oryzæ	24
acids (fatty)	—	A. oryzæ	24
acids (ketone)	—	A. oryzæ	24
acids (monohydroxy)	—	A. oryzæ	24
adipate (KH)	—	A. oryzæ	15
alcohols (ketone)	—	A. oryzæ	24
alcohols (monohydric)	—	A. oryzæ	24
aldehydes	—	A. oryzæ	24
arabinose	+	A. effusus	20
arabinose	+	A. flavus	14, 20
arabinose	+	A. oryzæ	15, 24, 30
arabinose	—	A. oryzæ	20
arabinose	+	A. parasiticus	20
arabinose	+	A. tamarii	20
barley	+	A. oryzæ	2
beans	—	A. oryzæ	2
citrate (K)	—	A. oryzæ	31
comenate (Na)	—	A. oryzæ	15
dextrin	+	A. flavus	12
dihydroxy acetone	—	A. oryzæ	24
dihydroxy acetone	+	A. oryzæ	31
dimethyl pyrone	—	A. oryzæ	15
dulcitol	+	A. oryzæ	24, 30
erythritol	—	A. oryzæ	24
ethylene glycol	—	A. oryzæ	24, 31
fecula	+	A. flavus	14
fructose	+	A. effusus	20
fructose	+	A. flavus	14, 20
fructose	+	A. glaucus	6
fructose	+	A. oryzæ	24, 30

Organism	+ —	C—source	Reference
Acetic acid bacilli (10 sp.)	+	mannitol	19
Acetic acid bacilli (13 sp.)	—	mannitol	19
A. (species of)	+	glucose	32
A. (species of)	+	glycerol	32
A. (species of)	+	mannose	32
A. (species of)	+	sucrose	32
A. albus	+	rice (steamed)	21
A. candidus	+	rice (steamed)	21
A. effusus	+	arabinose	20
A. effusus	+	fructose	20
A. effusus	+	galactose	20
A. effusus	+	glucose	20
A. effusus	+	glycerol	20
A. effusus	+	lactose	20
A. effusus	+	mannitol	20
A. effusus	+	starch	20
A. effusus	+	xylose	20
A. flavus	+	arabinose	14, 20
A. flavus	+	fecula	14
A. flavus	+	fructose	14, 20
A. flavus	+	galactose	20
A. flavus	+	glucose	12, 14, 16, 20
A. flavus	+	glycerol	14, 20
A. flavus	+	glycolic acid	14
A. flavus	—	inulin	14
A. flavus	—	lactose	20
A. flavus	+	maize	14
A. flavus	+	mannitol	20
A. flavus	+	sucrose	14, 20
A. flavus	—	sucrose	35

TABLE II—CONTINUED

C—source	+ −	Organism	Reference	Organism	+ −	C—source	Reference
fructose	−	A. oryzæ	20	A. flavus	−	tartaric acid	14
fructose	+	A. parasiticus	20	A. flavus	+	xylose	12, 14, 20
fructose	+	A. tamarii	20	A. glaucus	+	fructose	6
galactose	+	A. effusus	20	A. glaucus	+	glycerol	6
galactose	+	A. flavus	20	A. glaucus	+	sucrose	6
galactose	+	A. oryzæ	20, 24	A. nidulans	+	rice (steamed)	21
galactose	+	A. parasiticus	20	A. oryzæ	+	xylose	21
galactose	+	A. tamarii	20	A. oryzæ	−	acids (amino)	24
gluconate (Ca)	−	A. oryzæ	31	A. oryzæ	−	acids (fatty)	24
gluconic acid	+	A. oryzæ	24	A. oryzæ	−	acids (ketone)	24
glucose	+	A. (species of)	32	A. oryzæ	−	acids (monohydroxy)	24
glucose	+	A. effusus	20	A. oryzæ	−	adipate (KH)	15
glucose	+	A. flavus	12, 14, 16, 20	A. oryzæ	−	alcohols (ketone)	24
glucose	+	A. oryzæ	15, 20, 24, 27, 30	A. oryzæ	−	alcohols (monohydroxy)	24
glucose	+	A. parasiticus	20	A. oryzæ	−	aldehydes	24
glucose	+	A. tamarii	20	A. oryzæ	+	arabinose	15, 24, 30
glucose	+	P. dalesæ	20	A. oryzæ	−	arabinose	20
glucuronic acid	−	A. oryzæ	15	A. oryzæ	+	barley	2
glyceraldehyde	−	A. oryzæ	24	A. oryzæ	−	beans	2
glyceric acid	−	A. oryzæ	31	A. oryzæ	−	citrate (K)	31
glycerol	+	A. (species of)	32	A. oryzæ	−	comenate (Na)	15
glycerol	+	A. effusus	20	A. oryzæ	+	dihydroxy acetone	31
glycerol	+	A. flavus	14, 20	A. oryzæ	−	dihydroxy acetone	24
glycerol	+	A. glaucus	6	A. oryzæ	−	dimethyl pyrone	15
glycerol	+	A. oryzæ	24, 30, 31	A. oryzæ	+	dulcitol	24, 30
glycerol	−	A. oryzæ	20	A. oryzæ	−	erythritol	24
glycerol	+	A. parasiticus	20	A oryzæ	−	ethylene glycol	24, 31
glycerol	+	A. tamarii	20	A. oryzæ	+	fructose	24, 30
glycerol beta-phosphate	+	A. oryzæ	24	A. oryzæ	−	fructose	20
glycolic acid	−	A. flavus	14	A. oryzæ	+	galactose	20, 24
inositol	+	A. oryzæ	24, 30	A. oryzæ	−	gluconate (Ca)	31

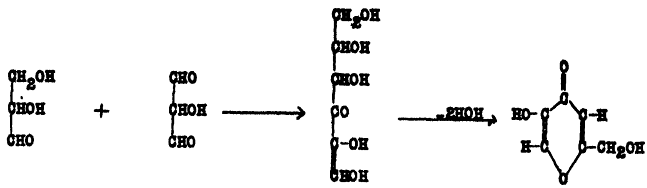
TABLE II—Continued

C—source	+ —	Organism	Reference	Organism	+ —	C—source	Reference
inulin	—	A. flavus	14	A. oryzæ	+	gluconic acid	24
inulin	+	A. oryzæ	24	A. oryzæ	+	glucose	15, 20, 24, 27, 30
ketones	—	A. oryzæ	24	A. oryzæ	—	glucuronic acid	15
lactose	+	A. effusus	20	A. oryzæ	—	glyceraldehyde	24
lactose	—	A. flavus	20	A. oryzæ	—	glyceric acid	31
lactose	—	A. oryzæ	20, 24	A. oryzæ	+	glycerol	24, 30, 21
lactose	—	A. parasiticus	20	A. oryzæ	—	glycerol	20
lactose	+	A. tamarii	20	A. oryzæ	+	glycerol beta-phosphate	24
maize	+	A. flavus	14	A. oryzæ	+	inositol	24, 30
maize	+	A. oryzæ	2	A. oryzæ	+	inulin	24
maltose	+	A. oryzæ	24	A. oryzæ	—	ketones	24
mannitol	+	Acetic acid bacilli (10 sp.)	19	A. oryzæ	—	lactose	20, 24
mannitol	—	Acetic acid bacilli (13 sp.)	19	A. oryzæ	+	maize	2
mannitol	+	A. effusus	20	A. oryzæ	+	maltose	24
mannitol	+	A. flavus	20	A. oryzæ	+	mannitol	30
mannitol	+	A. oryzæ	30	A. oryzæ	—	mannitol	20, 24
mannitol	—	A. oryzæ	20, 24	A. oryzæ	+	mannose	24, 30
mannitol	+	A. parasiticus	20	A. oryzæ	—	alpha-methyl glucoside	24
mannitol	+	A. tamarii	20	A. oryzæ	+	millet	2
mannose	+	A. (species of)	32	A. oryzæ	+	oats	2
mannose	+	A. oryzæ	24, 30	A. oryzæ	—	peas	2
alpha-methyl glucoside	—	A. oryzæ	24	A. oryzæ	—	pyroracemic acid	15
millet	+	A. oryzæ	2	A. oryzæ	—	rhamnose	24
oats	+	A. oryzæ	2	A. oryzæ	+	rice (steamed)	1, 21
peas	—	A. oryzæ	2	A. oryzæ	+	rye	2
pyroracemic acid	—	A. oryzæ	15	A. oryzæ	+	saccharic acid	24
rhamnose	—	A. oryzæ	24	A. oryzæ	—	saccharate (KH)	31
rice (steamed)	+	A. albus	21	A. oryzæ	+	sorbitol	24
rice (steamed)	+	A. candidus	2	A. oryzæ	—	starch	20
rice (steamed)	+	A. nidulans	2	A. oryzæ	+	sucrose	24, 26
rice (steamed)	+	A. oryzæ	1, 21	A. oryzæ	—	sucrose	20

TABLE II—CONCLUDED

C—source	+ —	Organism	Reference	Organism	+ —	C—source	Reference
rye	+	A. oryzæ	2	A. oryzæ	+	sweet potatoes	2
saccharic acid	—	A. oryzæ	24	A. oryzæ	+	tartaric acid	30
saccharate (KH)	—	A. oryzæ	31	A. oryzæ	+	wheat	2
sorbitol	+	A. oryzæ	24	A. oryzæ	+	xylose	15, 24, 30
starch	+	A. effusus	20	A. oryzæ	—	xylose	20
starch	+	A. flavus	12, 20	A. parasiticus	+	arabinose	20
starch	—	A. oryzæ	20	A. parasiticus	+	fructose	20
starch	+	A. parasiticus	20	A. parasiticus	+	galactose	20
starch	+	A. tamarii	20	A. parasiticus	+	glucose	20
sucrose	+	A. (species of)	32	A. parasiticus	+	glycerol	20
sucrose	+	A. effusus	20	A. parasiticus	—	lactose	20
sucrose	+	A. flavus	14, 20	A. parasiticus	+	mannitol	20
sucrose	—	A. flavus	35	A. parasiticus	+	starch	20
sucrose	+	A. oryzæ	24, 26	A. parasiticus	+	sucrose	20
sucrose	—	A. oryzæ	20	A. parasiticus	+	xylose	20
sucrose	+	A. parasiticus	20	A. tamarii	+	arabinose	20
sucrose	+	A. tamarii	20	A. tamarii	+	fructose	20
sweet potatoes	+	A. oryzæ	2	A. tamarii	+	galactose	20
tartaric acid	—	A. fllavus	14	A. tamarii	+	glucose	20
tartaric acid	+	A. oryzæ	30	A. tamarii	+	glycerol	20
xylose	+	A. effusus	20	A. tamarii	+	lactose	20
xylose	+	A. flavus	12, 14, 20	A. tamarii	+	mannitol	20
xylose	+	A. oryzæ	15, 24, 30	A. tamarii	+	starch	20
xylose	—	A. oryzæ	20	A. tamarii	+	sucrose	20
xylose	+	A. parasiticus	20	A. tamarii	+	xylose	20
xylose	+	A. tamarii	20	P. daleæ	+	glucose	20
wheat	+	A. oryzæ	2				

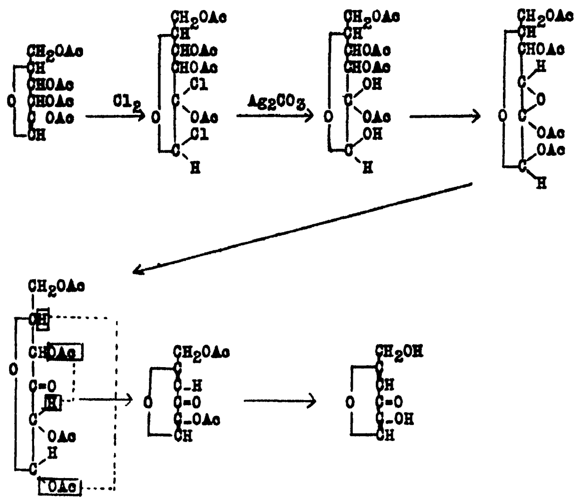
Nothing of a definite nature may be said about the mechanism by which köjic acid is formed through fermentation. Haworth (*33*) thought that because of its structural relationship to glucose, it might be formed through oxidation and dehydration of glucose, which view becomes doubtful, or at least only partially true, with the knowledge that the ketohexose fructose (*6, 14, 20, 24, 30*) and the pentoses arabinose (*14, 15, 20, 24, 30*) and xylose (*12, 14, 15, 20, 24, 30*) yield köjic acid. The fact that so many different compounds can be used for this purpose suggests that the formation of köjic acid is preceded by fragmentation with subsequent coupling of the residues to form a six-carbon chain. Corbellini and Gregorini (*14*) believe that köjic acid may result from the condensation of two molecules of different oxidation products of glycerol according to the following equation:



a reaction which is analogous to that of Neuberg and Hirsch (*34*). The formation of köjic acid from pentoses raises the question as to whether the yield would be restricted by the single 3-carbon chain capable of being formed from one molecule of a pentose or whether both the 2- and 3-carbon chains are available. It is known that acetic acid bacteria can convert sugars and starch into acetic acid with its 2-carbon chain. Mannitol has been fermented to köjic acid with acetic acid bacteria by Takahashi and Asai (*19*), which makes it at least possible that the 2-carbon chains are used in its formation. Moreover, Yuill (*35*), when fermenting sucrose with an *A. flavus*, obtained ethyl alcohol, but no köjic acid. Here we have a case of an organism, which usually produced köjic acid under the conditions employed, forming a 2-carbon atom compound. Although it has been reported that *A. glaucus* ferments köjic acid to alcohol (*6*), it probably cannot be so considered in Yuill's experiments, as köjic acid should be present in sufficient quantities to give a test with ferric chloride. It is significant also that Bernhour (*36*) found small quantities of acetaldehyde, along with the citric acid, in media fermented by *A. niger*. Whether it be acetaldehyde or not, there are many reasons to believe, as has been pointed out by Herrick (*16*), that there is a single reactive compound of low molecular weight, perhaps containing but two carbon atoms, which represents the starting point for the synthesis of numerous fermentation products. It is interesting to note that a starchlike compound has been detected in the mats of an *A. flavus* grown on xylose media (*12*). If this material is starch, it probably means that it is formed from glucose resulting from the condensation of xylose fragments. It is still possible, therefore, that Haworth's mechanism correctly represents the last step in köjic formation if we think of it, as well as the starch, as coming from glucose.

The preparation of köjic acid by a purely chemical method has been successfully accomplished by Maurer (*37*) from glucose. Later Maurer and Mül-

ler (*38*) prepared it in a very similar way from galactose. The method consisted in treating tetraacetyl-2-hydroxy glucal with chlorine in cold ether, forming one of four possible isomeric dichlorides, which gave, from an ether solution cooled to —20° C., hygroscopic crystals melting at 70° C. These crystals, in ether, to which a few drops of water had been added, react with Ag_2CO_3, giving 2, 3, 4, 6-tetraacetyl glucosone hydrate, melting at 112° C., which, when permitted to stand in the ice box in acetic anhydride-pyridine solution, forms the diacetate of köjic acid. The diacetate, dissolved in a solution of ammonia and methyl alcohol, changes over a period of 48 hours into a product whose diacetate and dibenzoate were identical in every respect with those of köjic acid obtained by fermentation with *A. oryzæ*. The suggested reactions for these changes are as follows:



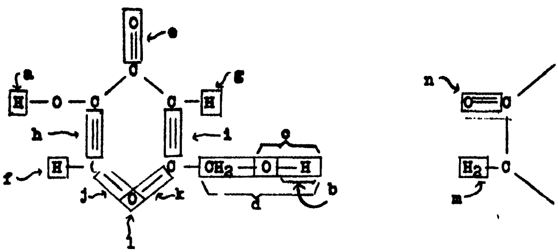
Tetraacetyl galactosone hydrate changes in the presence of acetic anhydride and pyridine to the diacetate of köjic acid, as does tetraacetyl glucosone hydrate, even though the arrangements of the substituents on carbon atom 4 are the reverse of that in the glucose derivative.

V. PHYSICAL PROPERTIES

Köjic acid crystallizes in the form of prismatic needles (*2, 6*), which sublime in vacuo without change (*3*) and, according to Traeta-Mosca (*6*), turn violet in the light. It is readily soluble in water (*3, 6*), alcohol (*3, 6*), ethyl acetate (*3*), and acetone (*6*), less soluble in ether (*3, 6*), alcohol-ether (*6*), chloroform (*3*), and pyridine (*3*), and scarcely at all in other solvents (*3, 6*). The melting point has been determined by a number of different workers, whose results are given as follows: 152° C. (*3*), 154° C. (*6*), 154° C. (*32*), 153-54° C. (*14*), 152.3° C. (*12*), 151-52° C. (*20*), 152° C. (*37*), and 152.6° C. (*16*), the average of which is 152.7° C., or almost exactly that obtained by Herrick.

VI. CHEMICAL BEHAVIOR OF KOJIC ACID AND ITS DERIVATIVES

It will be convenient and advantageous to outline and consider the observed chemical properties of köjic acid according to the structures of the molecule undergoing reaction. Each part or structure may be identified by its letter as given in the formulæ below:



(*a*) The hydrogen atom of this position is very similar in its behavior to that of the phenols. Its solutions are acid to congo red (*2*), phenolphthalein (*2, 6*), rosalic acid (*2*), litmus (*2*) and methyl orange (*2*), and expels carbon dioxide from solutions of alkali carbonates and bicarbonates (*2*). When carbon dioxide is passed into a concentrated solution of its sodium salt, köjic acid is precipitated (*3*). However, it is not precipitated by the addition of aqueous or ammoniacal silver nitrate, neutral, basic, or ammoniacal lead acetate, mercuric chloride, tannin, phosphotungstic, or phosphomolybdic acids (*2*).

When present in concentrations greater than one part in two hundred thousand, it gives with solutions of ferric chloride an intense red coloration, which disappears with addition of dilute acids and reappears when made neutral (*2, 14*). 5-hydroxy-2-chloromethyl-γ-pyrone gives a purple color (*4*), 2-hydroxymethyl-5, 6-dihydroxy-γ-pyrone a transitory green color (*3*), and 4, 5-dihydroxy-2-methyl pyridine a violet color with ferric chloride.

Of the metal derivatives which have been prepared from köjic acid and its derivatives, the copper salt of kojic acid (*2, 3, 6, 14*) is its most important and most characteristic salt. It forms light-green rhombic crystals, soluble in dilute acids, acetic acid and dilute ammonium hydroxide, the composition of which has been reported as $(C_6H_5O_4)_2Cu$ (*3*), $(C_6H_5O_4)_2Cu.H_2O$ (*6*) and $(C_6H_5O_4)_2Cu.\frac{1}{2}H_2O$ (*16*). The carefully washed copper salt, if dried at 100° C., corresponds to the last of the above formulæ (*12, 16*). The ease and completeness of precipitation of this salt makes it of value in the isolation of (*3*) and estimation of köjic acid (*12, 16*). Other salts which have been prepared:

1. From köjic acid:
   $C_6H_5O_4Na$ (*6*)
   $(C_6H_5O_4)_2Ba.2C_6H_6O_4$ (*3*)
   $(C_6H_5O_4)_2Ca.2C_6H_6O_4.4H_2O$ (*3*)
   $(C_6H_5O_4)_2Sr.2C_6H_6O_4.4H_2O$ (*3*)
2. From 2-hydroxy methyl-5-hydroxy-6-bromo-γ-pyrone:
   $(C_6H_4O_4Br)_2Cu$ (*3*)
   $C_6H_5O_4Br.Pb.OAc$ (*3*)
   $C_6H_3O_4Br.Pb.ONO_2$ (*3*)

3. From 5, 6-dihydroxy-2-hydroxymethyl-γ-pyrone:
   $C_6H_4O_5.Cu$ (*3*)

Köjic acid also forms mercury derivatives, probably organo-mercury compounds, but their compositions have not been investigated (*12*).

The methyl ether of this position may be prepared in the usual manner with diazomethane (*3, 5, 7, 11*) or dimethyl sulfate (*3*). If it is desired to prepare 5-methoxy-2-hydroxy methyl-γ-pyrone, diazomethane should be used as the methylating agent as, with it, methylation tends to stop with one hydroxyl while with dimethyl sulfate it is difficult to keep both hydroxyl groups from being methylated (*3, 11*). When köjic acid is methylated with diazomethane in an ether solution, the yield of the monomethyl ether is nearly quantitative (*11*). Its melting point has been reported as 160-161° C. (*5*) and 165° C. (*7, 11*). The monoethyl ether (2-hydroxymethyl-5-ethoxy-γ-pyrone), melting at 110° C., is formed when köjic acid, ethyl p-toluene sulfonate, and sodium ethylate are permitted to react in absolute alcohol. Some köjic acid derivatives have been methylated, giving:

5-methoxy-2-chloromethyl-γ-pyrone	m.p. 119-121° C.	(*4*)
5-methoxy-2-methyl-γ-pyrone	m.p. 70-71° C.	(*4*)
5-methoxy-1, 2-dimethyl-γ-pyridone........	m.p. 98° C.	(*4*)

Esters of köjic acid and acetic, benzoic, and phenyl carbamic acids have been prepared by a number of investigators. In every case when acetylation was carried out with acetic anhydride or acetyl chloride, the diacetate, melting at 102° C., resulted (*2, 3, 6, 32*), while, with benzoyl chloride, the reaction may be so controlled as to give the monobenzoyl ester, melting at 135° C. (*2, 3*), and the dibenzoyl ester, melting at 137° C. (*2, 3, 6*). Refluxing köjic acid with benzoyl chloride in an ether solution gives the monobenzoate, while the dibenzoate results when köjic acid is treated with an aqueous alkaline solution of benzoyl chloride (*2*). The diphenyl carbamate, melting at 170° C., has also been prepared (*3*). Esters of some köjic acid derivatives are:

6-bromo-γ-pyrone-2, 4, diacetate...........	m.p. 94-95° C.	(*3*)
6-bromo-γ-pyrone-2, 5-dibenzoate	m.p. 133-134° C.	(*3*)
2-chloromethyl-γ-pyrone-5-benzoate	m.p. 117-118° C.	(*4*)
2-methyl-γ-pyrone-5-benzoate	m.p. 128-129° C.	(*4*)
2-methyl-γ-pyrone-5-phenyl carbamate	m.p. 186-188° C.	(*4*)

The effect of reduction on the methoxy groups in pyridones is to replace them with hydroxyl groups. Thus, 2, 5-dimethoxy-γ-pyridone reacts with hydriodic acid and red phosphorus when kept at 150-160° C. for several hours, to form 4, 5-dihydroxy-2-methyl pyridine, melting at 280° C. (*4*), and 5-methoxy-1, 2-dimethyl-γ-pyridone is reduced with sodium and amyl alcohol forming 5-hydroxy-1, 2-dimethyl-γ-pyridone with a melting point of 273-274° C. (*11*).

(*b*) All of the ethers of this position which have been prepared have been considered along with those of position (*a*). It may be observed that there is no case where such derivatives have been made of position (*b*) without first forming those of position (*a*). Derivatives of both positions may be prepared from köjic acid or the mono derivatives of position (*a*). There is one method of obtaining the dimethyl ether not mentioned above which is carried out by

treating the monomethyl ether with methyl iodide and dry silver oxide (*11*). The ether and ester derivatives of this position are:

$C_6H_4O_2(OMe)_2$ .... m.p. 90° C. (*3*) m.p. 89-90° C. (*11*)
$C_6H_4O_2(OAc)_2$ .... m.p. 102° C. (*2, 3, 32*)
$C_6H_4O_2(OBz)_2$ .... m.p. 135° C. (*2*) m.p. 136° C. (*3*)
$C_6H_4O_2(OCONHC_6H_5)_2$, m.p. 170° C. (*3*)

(*c*) Köjic acid, when treated with thionyl chloride, which has previously been freed from sulfur chlorides, reacts vigorously, giving an 80 per cent yield of 5-hydroxy-2-chloromethyl-γ-pyrone which distills with steam and melts at 166-167° C. Reduction of this compound with zinc and acetic acid replaces the chlorine with hydrogen forming allomaltol, 5-hydroxy-2-methyl-γ-pyrone, which is also volatile with steam, and melts at 166° C. Potassium iodide in acetone reacts with the chlorine compound replacing the chlorine with iodine, giving a product which gradually loses iodine upon heating. The monomethyl ether of the 5-hydroxy-2-chloro-methyl-γ-pyrone also reacts with potassium iodide in acetone, giving the corresponding iodine compound which melts at 135-137° C. Both iodo derivatives have been boiled in benzene solution with silver nitrite, but without the formation of nitro derivatives; with 2-iodomethyl-5-hydroxy-γ-pyrone the silver nitrite was reduced to silver, but with 2-iodomethyl-5-methoxy-γ-pyrone a crystalline compound, melting at 175-176° C., was obtained in small quantities. When 2-methoxymethyl-5-methoxy-γ-pyridone is reduced with hydriodic acid and red phosphorus at 150-160° C., for several hours the methoxy methyl group is reduced to the methyl group to form 4, 5-dihydroxy-2-methyl pyridine, which melts at 280° C. (*4*).

(*d*) Efforts have been made to convert köjic acid and its derivatives into comenic acid and its derivatives and the reverse by oxidation-reduction methods of which the following have been unsuccessful (*4*):

(1) Oxidation of 5-benzoyloxy-2-hydroxymethyl-γ-pyrone with potassium permanganate.

(2) Oxidation of 5-ethoxy-2-hydroxymethyl-γ-pyrone with potassium permanganate.

(3) Oxidation of 5-ethoxy-2-hydroxymethy-γ-pyridone with potassium permanganate.

(4) Oxidation of 5-hydroxy-2-chloromethyl-γ-pyrone with lead nitrate.

(5) An indirect oxidation designed to replace the alcoholic hydroxyl with chlorine, iodine, and nitro groups successively, reducing the nitro group to the oxime to be converted first into the nitrile and later hydrolyzed to the carboxyl group.

(6) Reduction of the methyl ethers of methyl and ethyl comenates by means of sodium in ether and toluene solutions and in aqueous solution in the presence of boric acid (*40*) with hope of obtaining the aldehyde.

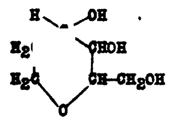
(7) Reduction of the methyl ether of comenyl chloride with hydrogen in xylene toluene, and benzene solutions with palladinized barium sulfate and kieselguhr as catalysts (*41*). If the aldehyde is formed, it is so unstable that it polymerizes at once to a resinous substance which inhibits further catalytic action.

(8) Reduction of the methyl ether of comenyl chloride through the anilide, phenyl iminochloride, diphenyl amidine and diphenyl methylene diamine (*42*). No aldehyde was formed.

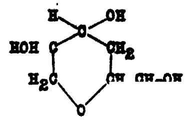
Other efforts to oxidize or reduce köjic acid or its derivatives have been more successful. 2-hydroxymethyl-5-methoxy-γ-pyrone in acetone solution is oxidized to the methyl ether of comenic acid by potassium permanganate, while 2-hydroxymethyl-5-methoxy-γ-pyridone is oxidized in aqueous solution by potassium permanganate, forming 5-methoxy-γ-pyridone-2-carboxylic acid decomposing at 249-250° C. (the value 269° C. was given in an earlier paper) (*5*). 2-hydroxymethyl-5-methoxy-γ-pyridone is oxidized also when it is permitted to stand with nitric acid for several days at room temperature, yielding 5-methoxy-γ-pyridone-2-carboxylic acid, which has a melting point of 267° C. With diazomethane the acid formed the methyl ester of 5-methoxy-1-methyl-γ-pyridone-2-carboxylic acid which, when recrystallized from ethyl alcohol, gave almost white soft crystals which turn yellow on keeping and have an odor recalling that of new-mown hay. These crystals, when heated, soften at 94° C. and melt at 134° C. (*11*). 5-methoxy-2-methoxy methyl-1-methyl-γ-pyridone in aqueous solution and at the temperature of cold running water is reduced, over a period of four hours, with sodium amalgam to 5-methoxy-1, 2-dimethyl-γ-pyridone, the hydrated form melting at 95° C. and the anhydrous form at 150° C. By a similar process the same product may be prepared from 5-methoxy-2-hydroxy-methyl-1-methyl-γ-pyridone. The picrate of the product melts at 208° C. (*11*). It has not been possible to convert the hydroxy methyl group into the β-hydroxy ethyl group through the chloromethyl and cyanomethyl compounds. The chloromethyl compound is readily formed, but it is completely resinified by boiling with alcohol-aqueous potassium cyanide (*11*).

(*e*) The köjic acid molecule is capable of absorbing six atoms of hydrogen without ring splitting, four at the double bonds and two at the carbonyl group. In some cases when reduction occurs in the presence of catalysts the reaction stops with the addition of four hydrogen atoms, while in other cases six are absorbed. Wijkman found that six atoms were absorbed in the presence of colloidal platinum and thought it probable that hydroglucal was formed (*32*), principally because of the assumption by Traeta-Mosca (*6, 7*) that köjic acid is 2-hydroxymethyl-3-hydroxy-γ-pyrone, and the fact that the melting point of the reduction product of köjic acid agreed rather closely with the melting point of hydroglucal as determined by Fischer (*43*). Traeta-Mosca reduced köjic acid in the presence of palladium and found that both four (*6*) and six (*7*) hydrogen atoms were absorbed, but analyses of products were not given. Armit and Nolan observed the absorption of six hydrogen atoms when köjic acid and its methyl ethers were hydrogenated in the presence of colloidal palladium, but analysis of the product showed an increase of only four hydrogen atoms. They assumed that their product was a mixture in the explanation of this discrepancy (*11*). Recently Maurer (*39*) reduced köjic acid in the presence of colloidal palladium obtaining a product which was proved to be tetrahydro köjic acid by the fact that it forms an osozone identical with that obtained from the parent diketone of tetra acetyl hydroxy glucal by

Bergman and Zervae (*44*). This makes it very probable that Wijkman's product was not hydroglucal—



but



Because of their failure to reduce the pyridone derivatives of köjic acid directly, Armit and Nolan tried the Grignard reaction in an attempt to form the tertiary alcohol group at the ketone position, but only flesh-pink colored addition compounds, which readily regenerated the original materials with water, dilute acids and ammonium chloride solution, resulted (*11*).

(*f*) When treated with bromine, köjic acid may undergo both addition and substitution reactions, depending upon the conditions employed. With bromine water a product is formed which is probably 2-hydroxymethyl-5-hydroxy-6-bromo-γ-pyrone, melting at 159-160° C., which reacts with barium hydroxide solution to give a poor yield of 2-hydroxy-methyl-5, 6-dihydroxy-γ-pyrone (*3*). 2-methyl-5-hydroxymethyl-γ-pyrone in a like manner reacts with bromine to form 2-methyl-5-hydroxy-6-bromo-γ-pyrone melting at 171-173° C. (*4*). Diazonium derivatives of köjic acid form readily. Phenyldiazonium acetate and köjic acid in a sealed tube form 2-hydroxymethyl-5-hydroxy-6-benzene azo-γ-pyrone melting at 146-147° C. (*3*), while 2-methyl-5-hydroxy-6-benzeneazo-γ-pyrone, with no definite melting point, is formed from 2-methyl-5-hydroxy-γ-pyrone and phenyldiazonium salts (*4*). Numerous other azo derivatives, these with dyeing properties, have been prepared (*12*).

(*g*) No reactions of this position have been noted.

(*h*) Part of the reduction reactions of this position as well as of position (*i*) have been considered necessarily in connection with the reduction of the ketone group since the double bonds are more susceptible to hydrogenation than the ketone. It has been possible, as stated above, to control the reduction so that only the double bonds are attacked. Traeta-Mosca noted the absorption of four hydrogen atoms by köjic acid with palladium as catalyst. The resulting compound is yellow and transparent and has the consistency of honey. It ferments with yeast, giving ethyl alcohol, and reacts with bromine to give white plates melting at 199° C. (*6*). According to Armit and Nolan, 2-methoxymethyl-5-methoxy-γ-pyrone, when hydrogenated under two atmospheres pressure in the presence of colloidal palladium, yields a product the analysis of which indicated the absorption of six hydrogen atoms from the determined carbon content, but the absorption of four hydrogen atoms from the determined hydrogen content. The ether was not demethylated in the process, as treatment with silver oxide and methyl iodide shows. The slow formation of a phenyl hydrazone possibly indicates that the product is the ether of tetrahydro köjic acid, although the hydrazone may be accounted for by the oxidation of a secondary alcohol and subsequent condensation (*11*). Maurer (*39*), by shaking köjic acid with colloidal palladium in an atmosphere of hydrogen, succeeded in forming a product which reacts with phenyl hydrazine to give an osozone identical with that formed by Bergman and Zervae (*44*) from tetra acetyl oxy glucal, which shows that, in this reduction, four hydrogen atoms have been absorbed, forming tetra hydro köjic acid.

Wijkman, in a bromine titration, observed the absorption of bromine sufficient to saturate two double bonds. Experimental conditions were not given (*32*).

As with the α-diketones, köjic acid possesses a labile hydrogen atom—the hydrogen atom of the nuclear hydroxyl group. The migration of this hydrogen atom will alternately saturate and unsaturate the double bond of this position, as is shown by the behavior of köjic acid with ferric chloride solution and bromine. The addition of bromine destroys the intense red color of a köjic acid-ferric chloride solution, but the color returns upon standing. Alternate addition of bromine and standing may be continued until the köjic acid is gone (*12*).

(*i*) The reactions of this position are the same as those of position (*h*) except for isomerization.

(*j, k*) Some treatments of the köjic acid molecule are so rigorous that it is fragmented. With potassium permanganate in alkaline or alkali carbonate solution it is oxidized yielding oxalic acid as one of the products (*2*). Köjic acid dimethyl ether is hydroyzed by barium hydroxide, giving equimolecular proportions of formic acid, methoxy acetic acid, and methoxy acetone (*3*). 5-methoxy köjic acid when boiled with calcium or barium hydroxide yields a product with a fruity odor which reduces Fehling's solution, moist silver oxide and gives the iodoform reaction (*7*). 5-benzoyl köjic acid and potassium permanganate in acetone give oxalic acid, formic acid and benzoic acid in addition to unused köjic acid (*4*). The action of an alkaline iodine solution upon köjic acid has been carefully studied by Birkinshaw and Raistrick, there being formed quantitatively from one mole of köjic acid one mole of iodoform, one mole of oxalic acid, one mole of formic acid, and one mole of glyoxylic acid. Their mechanism for this reaction has been given above (*17*).

(*l*) A characteristic reaction of the γ-pyrones is the substitution of the oxygen atom of the oxygen bridge by nitrogen, which occurs when the pyrones are made to react with ammonia or primary amines. There are many instances where reactions of this type have been carried out with the derivatives of köjic acid. In preparing the pyridones the pyrone is heated with rather concentrated solutions of ammonia or amines, either in a sealed tube at 100° C. or by prolonged boiling at atmospheric pressure. The pyridone from the 5-methyl ether of köjic acid has been prepared, but investigators do not agree as to its melting point, the values having been reported as follows: 111-112°C. (*5*), 95° C. (*7*), and 173-175 ° C. (*11*). It is reasonable to believe that these irregularities were due to varying degree of hydration of the pyridone. 2-hydroxymethyl-5-methoxy-γ-pyridone is soluble in water, ethyl alcohol, methyl alcohol, pyridine and less soluble in acetone (*5*). Its picrate melts at 181-182° C. The 5-methyl ether of köji acid reacts also with methyl amine, forming 2-hydroxymethyl-5-methoxy-1-methyl-γ-pyridone, which melts at 205° C. (*5*) or 203-204° C. (*11*) and is soluble in water (*5, 11*), alcohol (*5, 11*), methyl alcohol (*5*), pyridine (*5*), acetic acid (*11*) and less so in acetone (*5*). Ammonia transforms the dimethyl ether of köjic acid to the corresponding pyridone whose hydrochloride, picrate, and chloroplatinate melt at 180-181° C., 177° C., and 172° C., respectively (*3, 4*). With methyl amine in methyl alcohol solution the dimethyl ether of köjic acid forms 5-methoxy-2-methoxy methyl-1-methyl-γ-pyridone, which when distilled sets to a hard glass, melting at 113° C., and which forms needles from its solution in methyl acetate which melt at 51° C. When dried

over sulfuric acid it losses three molecules of water, giving a product which melts at 113° C. It is readily soluble in water, alcohol, chloroform, pyridine, and slightly soluble in ether, benzene and light petroleum. With picric acid it forms a picrate, melting at 191° C., and with methyl iodide the methiodide melting at 116-118° C. (*11*). The pyridone corresponding to the 5-ethoxy köjic acid has been prepared whose picrate melts at 184-185° C. (*4*). The action of a methyl alcoholic solution of methyl amine upon diacetyl köjic acid does not result in the formation of a pyridone as might be expected; rather, there is formed the methyl amine salt of köjic acid melting at 130° C. after sintering at 125° C. (*11*).

Other properties have been observed by different investigators which cannot be classified conveniently because the knowledge of them is too meager. Köjic acid is rather stable in air (*2*), but reduces Fehling's solution and moist silver oxide (*3*). The monobromoköjic acid-lead acetate complex reacts with hydrogen sulfide in acetic acid solution to form a substance with the empirical formula $(C_6H_5O_4)_2S$, which melts at 210-212° C. (*3*). It has been found also that diacetyl köjic acid absorbs ten atoms of hydrogen per molecule when reduced in the presence of a mixture of ethyl alcohol, phosphorus trichloride, gum arabic, and palladous chloride. The product when distilled at 10-12 mm. pressure yields three fractions: 80-120° C., 138-144° C. and 180° C. (*11*).

(*m, n*) Other than the diazonium reactions no reactions are known definitely which involve these structures.

VII. POSSIBLE USEFULNESS

Up to the present time it cannot be definitely stated that uses have been found for köjic acid or any of its derivatives. Some effort has been expended in this direction and there are results which point to the probability of its becoming a very useful substance.

It seemed to Armit and Nolan (*11*) that a promising field lay in formation of synthetic drugs of the β-eucaine type from köjic acid, but they were unsuccessful in doing so with the methods which they employed. However, it is not unreasonable to assume that they will be more successful with continued effort, since the difficulty is mainly one of method rather than relationship.

Reed and Bushnell (*45*) have studied the effect of köjic acid on the growth of certain microörganisms and have found that, above certain minimum concentrations, it tends to inhibit the growth of gram-negative much more strongly than gram-positive microörganisms. Other work similar to this (*12*) has been started, and preliminary results warrant the hope that an important use may be found for köjic acid in this general field.

A considerable number of dyes, which may be said to belong to three different series, have been prepared (*12*). The dyeing qualities of these dyes vary considerably. Many of them are good in certain respects, but from fair to poor in others, while a few may be considered fair commercial dyes on cotton, silk and wool, as far as fastness to washing and light is concerned. Thus far, however, no dye has been prepared from köjic acid of such quality and cost as to permit it to compete with other dyes. It might be of interest to note here (*46*) that some of these dyes are of good quality in staining certain vegetable tissues which usually are considered as being difficult to stain.

It has been observed frequently (*12*) that köjic acid and its derivatives tend

to resinify under certain conditions. At least one of these resins has been used to form a lacquer of apparently good quality. Perhaps, if a detailed study should be made of this property, useful resins might result.

The above by no means exhausts the fields which might be explored to find uses for a product which may be produced in large quantities, if need be, by fermentation. An examination of its structure will show it to be a versatile substance in its behavior, a substance which should lend itself to the formation of many derivatives, some of which, certainly, may be studied with the view of finding uses for them and therefore of köjic acid itself.

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Analyses of Fragments from the Tusks of Four Specimens of Extinct Elephants Found in Kansas

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Through the courtesy of the Department of Geology of this College we were able to obtain fragments of mastodon and mammoth tusks sufficient for chemical analysis. Outside of a few scattered analyses of fossil bones the literature revealed only one article giving any analyses of such material. This is an article by A. T. Rogers found in the Bulletin of the Geological Society of America, volume 35, of September 30, 1924, pp. 535-556. This article gives many analyses of fossil bones of various animals, including one or two extinct elephants, but no analysis stated to be that of the tusks of these elephants. We decided, therefore, to analyze these fragments of tusks and the task of making the analyses was assigned to Mr. Wm. Edw. Moling, a graduate student in the Department of Chemistry of Kansas State College, who, in the fall of 1932, made the analyses of samples from four different specimens found in Kansas.

SPECIMEN No. I

Fragments of a mastodon tusk found in the Smoky Hill valley near Delphos, Kan. The material was chalk-like and almost pure white in color.

SPECIMEN No. II

This was a piece from a mammoth tusk found in gravel near Randolph, Kan. A cross section of the material showed three concentric layers: (1) an inner core about one inch in diameter, (2) a middle layer one-half inch thick with several radial cleavages, and (3) a whitish outer layer about one-sixteenth of an inch thick. The crevices were stained with a dark substance which had filtered in from the surrounding gravel. The sample was easily broken into large splinters, which had a mottled appearance on the surfaces, but not throughout the material itself.

SPECIMEN No. III

Consisted of pieces of a mastodon tusk found in Kansas, the exact location not known. This specimen was chalky and white, resembling specimen No. I.

SPECIMEN No. IV

This was a fragment of a tusk of a mastodon or mammoth found in the sand of the Blue river near Rocky Ford, Kan. This specimen differed in several respects from any of the preceding ones. Its concentric layers, about one-sixteenth of an inch thick, were more finely knit and the color was light brown. The material was hard and tough. It was apparently the outside, horny layer of a tusk, about 10 inches in diameter, which had been weathered considerably less than the other three specimens. Its composition had apparently been somewhat affected by its surroundings, as it contained some alumina and much more iron than the other specimens.

TABLE OF ANALYSES (PERCENTAGES)

(The samples all dissolved in hydrochloric acid with effervescence)

	No. I	*No. II*	*No. III*	*No. IV*
Calcium oxide	50.00	50.52	48.80	37.80
Phosphorus pentoxide	34.50	34.07	34.57	27.14
Carbon dioxide	7.40	6.10	6.20	5.16
Magnesium oxide	0.30	.....	.....	.....
Water (110° C.)	3.16	3.38	3.92	5.53
Insoluble residue	0.38	0.22	0.45	0.40
Organic matter (not protein)	2.92	3.91	4.92	.....
Protein (Kjeldahl-factor 6.35)	0.46	0.31	0.50	19.00
Ferric oxide	trace	0.05	trace	2.86
Total	99.12	98.56	99.36	97.89

TABLE OF FORMULÆ (MINERAL)

No. I................. $3\ Ca_3(PO_4)_2 \cdot 2\ Ca(CO_3.O) \cdot 2.16\ H_2O$

No. II............. $3\ Ca_3(PO_4)_2 \cdot 2.29\ Ca(CO_3.O) \cdot 2.35\ H_2O$

No. III............... $3\ Ca_3(PO_4)2 \cdot 1.74\ Ca(CO_3) \cdot 2.69\ H_2O$

No. IV................ $3\ Ca_3(PO_4)_2 \cdot 1.83\ Ca(CO_3) \cdot 4.8\ H_2O$

These analyses place the mineral matter of the four specimens of tusks analyzed under the formula for collophane, as given by A. F. Rogers for the composition of fossil bones in the article cited above.

Collophane: $3\ Ca_3(PO_4)_2 \cdot N\ Ca(CO_3.F_2.SO_4.O) \cdot (H_2O)x$ where $N = 1-2$ and x is variable.

Victoria Blue BX as Internal Indicator in Ceriometry

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Several internal oxidation-reduction indicators have been proposed for titrations with standard solutions of potassium bichromate and ceric sulfate (*1, 2*). Some of those which are applicable with potassium bichromate cannot be used with ceric sulfate solutions because of the high oxidation-reduction potential of the latter. Hence it was thought desirable to continue the search for other indicators of high oxidation-reduction potential.

Victoria blue BX,* a diphenylnaphthylmethane derivative manufactured by the Du Pont Company, has a more pronounced color change than any indicator we have studied, going from sky blue to a rather bright pink, which fades at once to a light pink. Although it is not a reversible indicator, the color change at the end point is exceptionally rapid and sharp. Overstepped end points can be redetermined by adding standard ferrous solution and a few more drops of indicator solution. Like ortho-phenanthroline, Victoria blue BX does not give a satisfactory color change when the stannous chloride method of reduction has been used. It serves admirably, however, when the iron has been reduced with cadmium, aluminum or zinc. An end point correction of 0.02 ml. should be made for accurate analysis, although for an accuracy of 0.20 per cent this correction is unnecessary when the usual volume of standard solution is used. The correction does not vary with volume within large limits.

The end point may be approached at any reasonable rate. Nearness to the end point is indicated first by a slight fading of the blue solution to a clear sky-blue, and a few tenths of a milliliter before the end point is reached, a red spot can be seen for an instant as each drop of standard solution is added. At the end point as little as 0.02 ml. of 0.1 molar ceric sulfate solution will easily produce the entire color change.

As a standard oxidizing solution, ceric sulfate has several advantages over potassium permanganate and potassium bichromate, but some disadvantages also. The first cost is considerably greater. Our standard solutions of ceric salts have not become constant in less than five or six weeks. During this period a precipitate slowly settles out. A solution made up with conductivity water in place of ordinary distilled water showed the same tendency. Cooling does not seem to hasten the separation.

METHOD FOR THE DETERMINATION OF IRON IN AN IRON ORE

To determine the usefulness of Victoria blue BX under practical conditions, several samples of the Sibley iron ore No. 27, containing 69.26 per cent iron, obtained from the U. S. Bureau of Standards, were analyzed according to the following procedure: Samples weighing from 0.2 to 0.3 gram each were treated with 30 ml. of 12 molar hydrochloric acid and digested just below the boiling point until only a siliceous residue remained. This was filtered off, washed, ignited, and fused with potassium pyrosulfate, the resulting melt being dissolved

* The color change of a similar dye, Victoria blue B, has recently been mentioned by Vanossi and Ferramola, Ann. chim. anal., *15*, 529 (Dec., 1933).

and added to the main filtrate. After the iron had been reduced with cadmium, the solution was diluted to about 250 ml., and 5 ml. of phosphoric acid (sp. gr. 1.70), 20 ml. of 5 molar sulfuric acid, and 5 drops of a 2 per cent alcoholic solution of Victoria blue BX were added. The resulting solution was titrated at once with a ceric sulfate solution that had been standardized against sodium oxalate. The phosphoric acid keeps the potential required to oxidize the ferrous iron at a minimum by removing the ferric ion in the form of a slightly dissociated ferric phosphate complex, thus protecting the indicator until the end point is reached. The total acid concentration should be kept low, as a concentration of more than 1 or 2 molar will affect the indicator.

The results, as shown by the following table, agree closely with the Bureau of Standards value. The electrometric end points, both with a calomel-platinum electrode system and with a tungsten-platinum system, are also concordant.

TITRATION OF IRON WITH CERIC SULFATE USING VICTORIA BLUE BX AS INTERNAL INDICATOR

	Weight of sample grams.	Ml. of $Ce(SO_4)_2$.	Fe value of solution.	Per cent Fe found.
$H_2SO_4 + H_3PO_4$	0.2387	31.88	0.005183	69.22
do.	0.2140	28.56	do.	69.17
do.	0.2109	28.16	do.	69.22
do.	0.2314	30.90	do.	69.21
Mean				69.21
H_2SO_4 alone	0.3213	42.89	0.005183	69.18
do.	0.2809	37.44	do.	69.17
do.	0.3233	42.83	0.005222	69.18
do.	0.3242	42.97	0.005222	69.21
Mean				69.19
Bureau of Standards value				69.26

MEAN VALUES CALCULATED FROM ELECTROMETRIC END POINT

Using H_2SO_4 and H_3PO_4	69.25
Using H_2SO_4 alone	69.28

We wish to thank Mr. J. D. Ingle for preparing the ortho-phenanthroline ferrous complex used in this research.

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The Preparation of Some New Azo Derivatives of Guaiacol I

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The literature records but few investigations of the preparation and properties of guaiacol coupled with diazotized amines. Since a number of closely related phenols have proved to possess value not only as dyes, but also as medicinals and bacteriocides, the synthesis of a number of these derivatives was undertaken. The preparation of the free bases of benzene-azo-guaiacol and guaiacol-diazo-benzene have been reported (*1*) and a number of acetyl derivatives of azo-guaiacol have been investigated (*2*), but guaiacol dyes analagous to methyl orange, Congo red, and orange II have not been described in the literature.

In this investigation a number of dyes have been prepared by coupling guaiacol with various diazotized amines. Some of the physical properties of the dyes have been determined. In all cases the sodium salt of the dye was obtained. Four dyes were obtained as the free bases. The free bases were obtained as a viscous tarry substance, which resisted most attempts at recrystallization.

All but a few of the amines employed in this investigation were readily soluble in dilute mineral acids, and could be diazotized by the slow addition of sodium nitrite solution to the amine dissolved in slightly more than the calculated theoretical quantity of dilute acid. The diazotizations were carried out in most cases at a temperature of 5° C. In the case of the naphthlamines and 1-naphthylamine 4-sulfonic acid, the diazotization was carried out at near 15° C. This procedure was used after consideration of some of the recent investigations of diazotizations and diazo compounds (*3*). The technique was altered in the case of 1-naphthylamine 4-sulfonic acid, since this amine exhibited solubility only in basic solution. This amine was dissolved in slightly more than the calculated theoretical amount of sodium hydroxide solution, containing the theoretical amount of sodium nitrite. The calculated amount of acid was then slowly added.

The solutions were constantly agitated during the diazotization by means of a mechanical stirrer. The diazotization was controlled by testing the progress of the reaction by the starch, potassium iodide, paper method.

Since it has been shown that the presence of free mineral acids in solutions of diazo chlorides and phenols interferes with their coupling, these coupling reactions were carried out by placing the guaiacol in about four times the theoretical amount of sodium hydroxide (*4*). This solution was then cooled below 10° C., to which the diazonium chloride was slowly added, thereby maintaining a decided alkalinity at all times. If necessary more NaOH was added. This was determined by the sharp color changes exhibited by these compounds in passing from basic to acid solution.

Immediate precipitation of the dye occurred only in the case of 1-naphthylamine 4-sulfonic acid and beta-naphthylamine. These dyes could be readily precipitated by the addition of a saturated solution of sodium chloride, but this was undesirable since the presence of the salt interfered with the analysis of the dye. After several preliminary investigations it was found that the dye

could be readily obtained without the addition of the salt solution by diazotizing and coupling in a rather concentrated solution. Some of the dyes would settle out immediately from the coupling solution due to their insolubility. The yields under these conditions were small. The remainder of the dye, however, could be obtained by treating the filtrate with a small amount of salt solution without the usual salt contamination.

The free bases of some of the dyes were obtained in two ways, first by the addition of dilute acids to the unprecipitated dyes, and second by coupling in acid solution. In either case a viscous tarry precipitate was obtained, which was filtered and allowed to stand for several days. In most instances this tarry precipitate changed to a brittle, solid mass. Some of the dyes were soluble in alcohol and could be crystallized from it by dilution with water. Four of the dyes crystallized from diluted alcohol in long needlelike crystals.

The solubility of these dyes was treated qualitatively. In general they were soluble in the usual organic solvents and a few inorganic solvents.

The individual preparation of three of the dyes is given below. These are typical of the ten dyes prepared.

O-Anisidine (free base) $C_{14}H_{14}O_3N_2$. A solution of 10 g. of o-anisidine in 13.5 c.c. of HCl (Sp. Gr. 1.18) and 100 c.c. of water was prepared, cooled to 5° C., and diazotized by the slow addition of 5.5 g. of sodium nitrite in 25 c.c. of water. The diazo solution was then slowly added to 10.1 g. of guaiacol dissolved in a solution of 3.6 g. of NaOH in 100 c.c. of water. The resulting solution was then allowed to stand overnight before filtering, to insure complete coupling. The resulting viscous tarry mass was then dissolved in 200 c.c. of ethyl alcohol. When all of the dye was in solution enough water was added to form a slight precipitate, which was redissolved by heating. Upon cooling 8 g. of red needle-like crystals settled out, which melted at 101.8° C.

O-Phenetidine (Na salt) $C_{15}H_{16}O_3N_2$. A solution of 10 g. of o-phenetidine in 12.7 c.c. of HCl (Sp. Gr. 1.18) and 100 c.c. of water was prepared, cooled to 5° C., and diazotized by the slow addition of 4.3 g. of sodium nitrite in 25 c.c. of water. The diazo solution was then slowly added to 9.05 g. of guaiacol dissolved in a solution containing 11 g. of sodium hydroxide and 100 c.c. of water. The coupled solution was allowed to stand overnight to insure complete coupling. The dye which formed was separated from the solution by filtration, and to the filtrate was added a saturated solution of sodium chloride to remove all traces of the dye. The yield was 6.5 g. of red powder.

1-Naphthylamine 4-Sulfonic Acid (Na salt) $C_{17}H_{14}O_5N_2S$. A solution was prepared containing 10 g. of 1-naphthylamine 4-sulfonic acid, 1.74 g. of sodium hydroxide, 2.9 g. of sodium nitrite, and 150 c.c. of water. After several preliminary trials, diazotization was most successfully carried out at room temperature, by slowly adding 8.7 c.c. of hydrochloric acid (sp. gr. 1.18). The resulting diazo solution was coupled by the addition of a solution of 5.35 g. of guaiacol dissolved in 10 g. of sodium hydroxide and 100 c.c. of water.

The dye began to precipitate immediately, but the solution was allowed to stand overnight to insure the complete coupling. After allowing the dye to stand overnight, it was filtered, and the filtrate treated with a saturated salt solution; however, no appreciable amount of dye was recovered from the filtrate. This type of procedure is general for all sulfonic derivatives of the aromatic amines.

TABLE I

This table summarizes the dyes prepared. In every case guaiacol was the phenol to be coupled with the diazotized amine.

Dye Prepared	Amine	Color	M. P.
4-hydroxy 3-2^1 methoxy-azo-benzene (free base)	o-anisidine	red brown needles	101.8
4-hydroxy 3-2^1 methoxy-azo-benzene (Na salt)	o-anisidine	red brown	above 360
4-hydroxy 3-3^1 methoxy-azo-benzene (Na salt)	m-anisidine	light brown	above 360
4-hydroxy 3-4^1 methoxy-azo-benzene (Na salt)	p-anisidine	light brown	above 360
4-hydroxy 3-methoxy 2^1-ethoxy-azo-benzene (free base)	o-phenetidine	red crystals	113.9
4-hydroxy 3-methoxy 2^1-ethoxy-azo-benzene (Na salt)	o-phenetidine	light brown	above 360
4-hydroxy 3-methoxy 3^1-ethoxy-azo-benzene (Na salt)	m-phenetidine	dark brown	above 360
4-hydroxy 3-methoxy 4^1-ethoxy-azo-benzene (Na salt)	p-phenetidine	red	above 360
4-hydroxy 3-methoxy 4^1-ethoxy-azo-benzene (free base)	p-phenetidine	yellow brown	95.1
4-hydroxy 3-methoxy-azo-alpha-naphthylamine (Na salt)	a-naphthylamine	light brown	above 360
4 hydroxy 3-methoxy-azo-beta-naphthylamine	b-naphthylamine	light brown	above 360
4-hydroxy 3-methoxy 4^1 sulfonic acid-naphthylene	l-naphthylamine 4-sulfonic acid	light brown	above 360
4-hydroxy 3-methoxy 1^1 4^1-dimethyl-azo-benzene (free base)	1-4-dimethyl amino benzene	yellowish-brown crystals	103.5

TABLE II

A summary of the analysis of the compounds prepared.

Dye Prepared	Grams of dye taken	Grams N	Theory, N per cent	Found, N per cent
4-hydroxy 3-2[1] methoxy-azo-benzene (free base)	.3191	.0347	10.85	10.89
4-hydroxy 3-2[1] methoxy-azo-benzene (Na salt)	.2378	.0243	10.00	10.20
4-hydroxy 3-3[1] methoxy-azo-benzene (Na salt)	.2876	.0289	10.00	10.03
4-hydroxy 3-4[1] methoxy-azo-benzene (Na salt)	.2631	.0261	10.00	10.03
4-hydroxy 3-methoxy 2[1] ethoxy-azo-benzene (Na salt)	.2781	.0288	10.29	10.34
4-hydroxy-3-methoxy 2[1] ethoxy-azo-benzene (Na salt)	.3207	.0305	9.52	9.57
4-hydroxy-3-methoxy 3[1] ethoxy-azo-benzene (Na salt)	.2421	.0321	9.52	9.59
4-hydroxy-3-methoxy 4[1] ethoxy-azo-benzene (Na salt)	.3159	.0300	9.52	9.48
4-hydroxy-3-methoxy 4[1] ethoxy-azo-benzene (free base)	.2486	.0253	10.29	10.19
4-hydroxy-3-methoxy 4[1] sulfonic acid-azo-naphthylene (Na salt)	.3598	.0248	6.96	6.94
4-hydroxy-3-methoxy-azo alpha naphthylene (Na salt)	.2765	.0248	9.33	9.33
4-hydroxy-3-methoxy-azo beta-nephthylene (Na salt)	.2898	.0262	9.33	9.41
1-4-dimethyl 2-amino benzene (free base)	.2532	.0305	12.07	12.04

CONCLUSION

A number of dyes have been prepared by coupling guaiacol with various diazotized amines. A variety of color was obtained ranging from red to dark brown, the tendency being toward a reddish brown.

The free bases of these dyes were found to be precipitated as viscous, tarry substances, which could be crystallized in only a few cases.

The sodium salts of these dyes were found to be slightly soluble in water, and in a number of organic solvents, while the free bases which were isolated were soluble only in organic solvents.

The dyes exhibit a definite color change in passing from acid to basic solution.

It is suspected that each of these dyes prepared would have more or less antiseptic value because of the phenolic group present. The determination of the phenol coefficients and the physiological effect of these dyes were left for subsequent investigation.

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Concerning the Preparation of Some Diazo-Thio-Ethers of Thio-Beta-Naphthol

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INTRODUCTION

Although aromatic mercaptans closely resemble phenols in their general character, it has as yet been found impossible to couple them directly with diazonium salts, so as to form thio-azo-derivatives. Hantzsch and Freese (*1*), in 1896, working with thio phenol, found that it coupled to form diazo-thio-ethers of the general type, R–N = N–S–R, which more closely resembled the diazo-amino type than the azo.

Their first preparation, obtained by diazotizing aniline and coupling with phenyl-mercaptan in a strongly alkaline solution, resulted in an extremely unstable, impure oil, which decomposed slowly with the evolution of nitrogen even at a temperature as low as —5° C. A very large excess of sodium hydroxide was necessary in order to keep decomposition at a minimum. It was impossible to obtain this compound in a state pure enough for analysis. Hantzsch and Freese assumed the diazo constitution since it was split by concentrated hydrochloric acid into benzene-diazonium chloride and thiophenol.

Their next derivative, obtained by treating the diazonium salt of p-chloro aniline with sodium carbonate until alkaline and coupling with a strong alkaline solution of phenyl mercaptan, was obtained as a yellow crystalline solid. During the coupling, which took place at 0° C., a small amount of nitrogen was evolved. The product obtained from this reaction was purified by evaporation from absolute ether and analyzed. The results from this analysis proved the diazo structure.

Derivatives of 2-4-di-bromo aniline and p-iodo aniline were prepared in a similar manner and were found to be unstable oils, incapable of analysis. The derivative formed from 2-4-di-chloro aniline was found to be a solid, which was purified and analyzed. p.-Nitraniline yielded a derivative, stable at 0° C., but it decomposed at slightly higher temperatures.

Perhaps their best example of a diazo-phenyl-ether was obtained from sulfanilic acid. Diazo-sulfanilic acid was dissolved in cold concentrated sodium hydroxide and added to the calculated amount of phenyl mercaptan. Coupling did not take place immediately and thus gave a chance to filter any possible impurities. Upon standing at 0° C., the crystals of the sodium salt of diazo-sulfanilic acid thiophenyl-ether settled out slowly. After filtering and washing with cold water, alcohol and ether, the compound was pure enough for analysis. The sodium salt of the thiophenyl-ether was apparently stable at ordinary temperatures in the dessicator. The aqueous solution was stable at 0° C., but decomposed at ordinary temperatures with the evolution of nitrogen and the development of the odor of thiophenol. Attempts to obtain the free acid, $H\text{-}SO_3\text{-}C_6H_4\text{-}N = N\text{-}S\text{-}C_6H_5$, were unsuccessful. The addition of hydrochloric acid immediately reformed phenyl mercaptan and diazo-sulfanilic acid.

The work of Hantzsch and Freese (*1*) was more or less substantiated by Fox and Pope (*2*), who prepared mainly substituted thio-azo derivatives of ben-

zene. Since their method of preparation involved the use of the xanthic esters by the method described by Leuckart (3) they were able in one instance to obtain a small amount of impure benzene-azo-phenyl mercaptan. After the xanthic ester had been hydrolyzed with strong potassium hydroxide solution, the mixture was acidified and an orange-colored precipitate of the thio-azo-derivative was obtained. It was shown that the substance was so easily oxidized that half of the amount formed was oxidized to the disulfide, even when working in an atmosphere of carbon dioxide. This shows that in no case did Hantzsch and Freese have an azo type compound.

Thio-beta-naphthol was substituted for p-thio cresol as coupling agent, which gave better results than thiophenol or thiocresol. All substances used were of the purest quality obtainable. Those corresponding to the Eastman "practical" or "technical" were recrystallized in order to prevent possible contamination of the final product by impurities.

SOME DERIVATIVES OF THIO-BETA-NAPHTHOL

Diazo-Benzene-Thio-Beta-Naphthyl-Ether

One gram of aniline was dissolved in 4.2 c. c. of concentrated hydrochloric acid and 50 c. c. of water. The resulting solution was cooled to 0° C. and diazotized by the addition of 0.7 gram sodium nitrite in a 10 per cent solution. Twenty per cent sodium hydroxide was added until the diazonium hydroxide which was at first precipitated, was redissolved as the diazotate. The solution was filtered to remove any possible impurities. The diazonium solution was slowly added to a solution of 1.7 grams thio-beta-naphthol dissolved in 50 c. c. of water and 2 grams of sodium hydroxide. The temperature at which coupling took place was —6° C. Immediately there was formed a very fine, bright yellow precipitate, which collected to form an orange-colored gum. Upon standing, this gum became solid without the evolution of gas. After standing for about two hours, the resulting compound was filtered by suction. It was then washed with ice water until free from sodium hydroxide. The thio-ether was transferred to a vacuum dessicator and kept in an ice box until the compound was thoroughly dry. The yield was poor, being about 20 per cent of theoretical.

Diazo-benzene-thio-beta-naphthyl-ether was found to be insoluble in water at ordinary temperatures. In cold alcohol it was somewhat soluble, and in alcohol at ordinary temperatures it dissolved quickly with the evolution of nitrogen. Cold ether readily dissolved the thio-ether. It melted at 59.5-60.5° C.

Analysis calculated for $C_6H_5\text{-}N=N\text{-}S\text{-}C_{10}H_7$: S, 12.13 per cent. Found, 12.07 per cent.

m-Diazo-Toluene-Thio-Beta-Naphthyl-Ether

One gram of m-toluidine was dissolved in 5 c. c. of concentrated hydrochloric acid and 40 c. c. water. It was diazotized at 0° C. in a manner similar to that described for aniline by the addition of 0.6 gram sodium nitrite. Twenty per cent sodium hydroxide was added until the diazonium hydroxide redissolved. One and five-tenths grams of thio-beta-naphthol were dissolved in 50 c. c. of water containing 1 gram sodium hydroxide. The diazotized solution was slowly added to the coupling solution, which had been previously cooled to 0° C. Again the same bright yellow precipitate was formed, which immediately

changed to a deep brown oil. Vigorous stirring was continued until the oil solidified, which required about thirty minutes. The precipitate was filtered, washed, and dried in the usual manner. The yield was poor, being about 30 per cent of theoretical.

m-Diazo-toluene-thio-beta-naphthyl-ether was found to be insoluble in water and alcohol at room temperature, but was readily soluble in ether. It melted at 59-61° C. with decomposition.

Analysis calculated for $CH_3\text{-}C_6H_4\text{-}N = N\text{-}S\text{-}C_{10}H_7$: S, 11.52 per cent. Found, 11.36 per cent.

Beta-Dizao-Naphthalene-Thio-Beta-Naphthyl-Ether

One gram of beta-naphthylamine was dissolved in 0.9 c. c. of concentrated hydrochloric acid and 25 c. c. hot water. As soon as the amine was in solution it was quickly cooled by the addition of ice to a temperature of 0° C. The hyrochloride salt was precipitated in the finely divided state by the addition of 2.1 c. c. concentrated hydrochloric acid. The details for the diazotization were the same as those of p-nitraniline. A solution of 0.25 gram sodium nitrite was required for complete diazotization. The diazotized solution was added very slowly to a solution of 1.1 grams thio-beta-naphthol and 6 grams sodium hydroxide dissolved in 40 c. c. water. There was precipitated immediately a light brown, finely divided precipitate, which did not change on standing. The precipitate was filtered, washed, and dried in a manner similar to those already described. The yield was almost theoretical.

Beta-diazo-naphthalene-thio-beta-naphthyl-ether was found to be insoluble in cold water and alcohol but was fairly soluble in ether. It melted at 101-102° C with decomposition.

Analysis calculated for $C_{10}H_7\text{-}N = N\text{-}S\text{-}C_{10}H_7$: S, 10.20 per cent. Found, 10.23 per cent.

Diazo-Sulfanilic Acid-Thio-Beta-Naphthyl-Ether

A sample of 2.5 grams of sulfanilic acid was dissolved in 0.7 gram sodium carbonate and 100 c. c. water. The solution was cooled to 2° C. and 6 c. c. of concentrated hydrochloric acid added. The solution was diazotized in the usual manner with 0.9 gram sodium nitrite. The diazo-sulfanilic acid was dissolved by the addition of 20 per cent sodium hydroxide. The diazotized solution was added to the coupling solution at 0° C., which was composed of 0.2 gram sodium hydroxide and 2.1 grams thio-beta-naphthol dissolved in 100 c. c. water. Immediately small crystalline plates of a beautiful yellow color separated. After standing for some time, the mixture was filtered and treated as previously described.

Diazo-sulfanilic acid-thio-beta-naphthyl-ether was found to be slightly soluble in cold water and moderately soluble in cold alcohol. It decomposed in ether, evolving nitrogen. Its melting point was above 275° C.

Analysis calculated for $NaO_3\text{-}S\text{-}C_6H_4\text{-}N = N\text{-}S\text{-}C_{10}H_7$: S, 17.51 per cent. Found, 17.64 per cent.

One sample of diazo-sulfanilic acid-thio-beta-naphthyl-ether was allowed to stand for three or four weeks before analysis. The results of the sulfur analysis, which were low, showed that the thio-ether will decompose on standing even when perfectly dry.

4-Sulfonic Acid-Diazo-Alpha-Naphthalene-Thio-Beta-Naphthyl-Ether

A sample of 2.5 grams of 1-naphthylamine 4-sulfonic acid was dissolved in 80 c. c. water and 1.1 grams of sodium carbonate. The resulting solution was cooled to 2° C. and 6.7 c. c. concentrated hydrochloric acid added. It was diazotized by the rapid addition of 0.75 gram sodium nitrite in a 10 per cent solution. The coupling solution consisted of 1.7 grams thio-beta naphthol, 2 grams sodium hydroxide and 40 c. c. water. Upon standing small yellow plates of the sodium salt of the ether slowly settled out. After standing in the cold overnight, they were filtered and treated in the usual manner.

The sodium salt of the thio-ether melted at a temperature above 240° C. At a temperature of 175° C. the yellow color turned to a gray-brown.

Analysis calculated for $NaO_3S\text{-}C_{10}H_6\text{-}N=N\text{-}S\text{-}C_{10}H_7$: S, 15.41 per cent. Found, 15.36 per cent.

A DERIVATIVE OF p-THIO-CRESOL

Diazo-Sulfanilic Acid Thio-Tolyl-Ether

Five grams of sulfanilic acid were dissolved in 50 c. c. water and 1.4 grams sodium carbonate; acidified by the addition of 10 c. c. of concentrated hydrochloric acid; and diazotized according to the method previously given for sulfanilic acid. After the diazonium chloride had been redissolved by means of sodium hydroxide, the solution was added to the coupling solution, which consisted of 3.3 grams of p-thio-cresol dissolved in 3 grams sodium hyroxide and 20 c. c. water. Beautiful gold-colored leaflets of the sodium salt of the ether separated out. The crystalline compound was filtered, washed with ice water several times, and allowed to dry in the vacuum dessicator in the cold.

It was very slightly soluble in ether. Warm or cold alcohol dissolved it readily with the evolution of nitrogen. In hydrochloric acid it reacted vigorously. The compound was stable in cold water, but water at ordinary temperatures caused it to decompose rapidly.

Analysis calculated for $NaO_3S\text{-}C_6H_4\text{-}N=N\text{-}S\text{-}C_6H_4\text{-}CH_3$: S, 19.46 per cent. Found, 19.60 per cent.

CONCLUSIONS

1. When diazotized amines are coupled with thio-beta-naphthol in alkaline solution, thio-ethers are obtained.
2. The temperature of coupling should not be above 0° Centigrade.
3. Lower temperatures tend to diminish the evolution of nitrogen, which accompanied the decomposition of some of the formations.
4. The addition of a large excess of sodium hydroxide increased the yield of only those compounds which were formed as sodium salts.
5. The colors of the diazo-thio-ethers ranged from yellow to brown.
6. Diazo-thio-ethers are extremely unstable. They must be kept cold and absolutely dry.

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The Contribution of Secondary-school Chemistry Courses to Proficiency in General Inorganic Chemistry and Qualitative Analysis in the University of Kansas.

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The present investigation was initiated with a view to determining whether the residuum of training carried over from secondary-school chemistry courses of the last decade has been detectable in any commensurably greater accomplishment in the first-year work in chemistry at the University of Kansas. For our purpose we have compared all the available university first-year chemistry records of regular students in Chemistry 2 in the fall and Chemistry 3 in the spring semester of the long sessions 1923-'24, 1924-'25, and 1932-'33.

No attempt was made to make scientific measurements of the students' aptitude for chemistry at the time of their entrance into the university class. It is assumed that the average innate capability for chemistry of a statistically large number of university students is practically independent of previous training in chemistry. On this basis, the semester grade is taken as the fair relative measure of the student's actual accomplishment in the university course.

The data obtained are assembled in Table 1. The mean, the median, and the lower and the upper quartiles were calculated using individual grades in percentages. The grade of A was counted 95 per cent; B, 85 per cent; C, 75 per cent; D, 65 per cent; and F, 45 per cent. There is no permanent grade of E. The relative number of A's, B's, C's, etc., in each vertical column is the percentage of the total number of students listed in that column who made a grade of A, B, C, etc., respectively. For example, of the 245 students who had high-school chemistry, 61 made a grade of A on Chemistry 2 in the fall semester. This is 24.90 per cent of the 245 students in that group; therefore, the relative number of A's is 24.90 per cent.

Of 477 fall-semester students of general inorganic chemistry, 297 continued the year's work by taking qualitative analysis the succeeding spring semester. The 245 fall-semester students who had high-school chemistry showed accomplishment consistently superior to that of the 232 who had no chemistry previously. In qualitative analysis in the spring semester, the superiority of those who had high-school training is less pronounced, but still quite definite. The mean, the median, and both the lower and the upper quartiles are all slightly higher for those who had preuniversity chemistry.

From the relative numbers of students who made grades of A, B, C, D, and F, respectively, it is seen that secondary-school chemistry courses decrease the percentage of failures in first semester university chemistry by almost one-half, decrease decidedly the percentage of low and medium grades, increase by 51 per cent the percentage of B's, and nearly double the percentage of A's. High-school chemistry courses very slightly decrease the percentages of failures and low grades in spring semester qualitative analysis, decrease considerably the percentage of medium grades, increase, by a bare margin, the percentage of B's, and nearly double the percentage of A's. That is to

say, in both the fall and the spring semester of university work, the effect of the previous secondary-school training in chemistry is to increase materially the percentage of the superior at the expense of the medium and low grades.

These contributions of the high-school courses are definitely very considerable in the first, and less, but still perceptible, in the second semester of university chemistry.

TABLE 1. Tabular comparison of the achievement of University of Kansas regular first-year chemistry students with and without previous secondary-school training in chemistry (1923–1933).

	Chemistry 2: General inorganic chemistry, fall semester.		Chemistry 3: Qualitative analysis, spring semester.	
	Had high-school chemistry.	No high-school chemistry.	Had high-school chemistry.	No high-school chemistry.
Number	245	232	157	140
	Per cent	*Per cent*	*Per cent*	*Per cent*
Mean	77.37	70.47	73.34	71.29
Median	81.80	73.02	75.13	73.41
Lower quartile	67.72	55.00	64.02	63.33
Upper quartile	89.97	84.47	85.93	82.07
Relative No. A's	24.90	13.79	15.92	8.57
Relative No. B's	30.61	20.26	22.29	20.71
Relative No. C's	16.33	22.84	24.20	31.43
Relative No. D's	13.88	18.10	21.02	21.43
Relative No. F's	14.29	25.00	16.56	17.86

Fluorides in Kansas Waters and Their Relation to Mottled Enamel

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Since the tooth defect called mottled enamel is now known to be caused by larger than normal amounts of fluorides in the drinking-water supply of the victim, information on the subject is of general interest. The defect first manifests itself by chalky white spots on the enamel of the permanent teeth, apparent as soon as the teeth are erupted into the mouth (*1*). Later these spots may become stained from buff to dark brown. The discoloration is unfortunately most marked on the labial surfaces of the upper incisors, and is therefore quite conspicuous, especially in severe cases. The brown areas are, of course, much more readily detected than is the earlier chalky appearance, and the discoloration is on this account sometimes erroneously described as the original sign of the trouble. In general, the severity of the mottling increases with the amount of fluoride in the water, and the duration of use of the water in the childhood years.

Microscopic studies (*2*) indicate that in mottled enamel the cementing substance between the crystalline rods does not form properly, and that the rods themselves have suffered damage indistinguishable from decalcification. Chemical analyses made to date have indicated no definite difference between normal and mottled enamel, but this result may be due to the difficulty of obtaining adequate samples uncontaminated by dentine. Further studies on these phases of the problem are still needed.

The fluorides in the water exert their harmful effect only while the enamel is being formed, and do not harm enamel which has once been laid down undamaged. Since the enamel of the temporary teeth is normally formed before birth, it is rarely affected, but the enamel of the permanent teeth is formed during childhood, and is subject to harm from fluoride-containing waters during this time. Since the enamel cannot repair itself, the injury, when once suffered, is a permanent one. On the other hand, if the child's drinking-water supply is low in fluorides and the permanent teeth consequently erupt with their enamel normal, no mottling is produced by use in adult life of drinking waters relatively high in fluorides.

No satisfactory method of repairing mottled enamel is known to dentists, although the appearance of the teeth can be somewhat improved. Studies by dentists indicate that the affected teeth are no more liable to decay than are normal ones, but when a cavity occurs it is difficult to make a filling hold against the defective enamel. Dentists find also that it is frequently difficult to persuade victims of mottled enamel to care for their teeth properly, when their efforts result in so little improvement in appearance.

Mottled enamel was first described in 1901, but received little attention until the publication of a careful study by Black and McKay in 1916 (*1*). McKay (*3*) has continued his interest in the problem since that time, and is responsible for much of our information about the characteristics and distribution of this

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disturbance. It has been reported from various parts of the world, places as scattered as Italy, Spain, Holland, Argentina, North Africa, and China. In the United States (*4*) it has been reported to date from communities in Texas, Colorado, New Mexico, California, Nevada, Oregon, Idaho, Kansas, Arkansas, Oklahoma, Iowa, Mississippi, Tennessee, Illinois, Minnesota; North Dakota, South Dakota, Utah, North Carolina, South Carolina and Virginia.

In every afflicted community it has been found that the defect is associated with the drinking water; practically 100 per cent of the children regularly using the water are affected, while none using water from another source has the defect. Investigation of community after community has confirmed the part played by the drinking water and has ruled out all other suspected factors, such as malnutrition, childhood diseases, improper care of the teeth, etc. Although teeth are frequently poorly developed from these other causes, mottled enamel is a separate defect and can readily be recognized as such.

Even before the exact cause of mottled enamel was known, its relationship to the drinking-water supply was so well established that on the basis of McKay's findings the communities of Bauxite, Ark. (*1*), and Oakley, Idaho (*5*) changed their sources of water supply because of the occurrence of mottled enamel. Enough time has elapsed since the change was made at Oakley, in 1925, to establish the fact that production of mottled enamel has ceased, and results at Bauxite, which has changed its water supply more recently, will be awaited with interest.

The relationship of fluorides to mottled enamel was established independently in 1931 by Smith, Lantz and Smith (*6*) of the University of Arizona, and by Churchill (*7*) of the Aluminum Company of America. The former workers succeeded in producing a condition resembling mottled enamel in white rats by adding to their diets either small amounts of fluoride salts or the concentrated residues from waters known to be associated with the production of mottled enamel. Churchill, as well as the Arizona workers, found relatively high amounts of fluorides in waters from communities in which mottled enamel had been reported and little or none in other waters.

Results of fluoride tests on Kansas waters confirm the work reported above. Determinations on all Kansas municipal supplies show that fluorides in excess of two parts per million occur only in waters from the few communities in which mottled enamel has been reported, and, in addition, that samples from communities reporting this defect have in all cases contained more than two parts per million of fluorides. However, the limit of safety cannot definitely be set at two parts per million until it is proven clearly that amounts slightly less than this are entirely safe. Of the 329 Kansas municipalities having public water supplies, the water of 126 or 38.3 per cent contains less than 0.6 p. p. m., of fluoride, 168 or 51.1 per cent have 0.6 to 1.0 p. p. m., 24 or 7.3 per cent have 1.1 to 1.5 p. p. m., 8 or 2.4 per cent have 1.6 to 2.0 p. p. m., none has between 2.1 and 3.0 p. p. m., and 3 or 0.9 per cent have more than 3.0 p. p. m.

Fluorides occur widely scattered, but are found in abundant quantity in relatively few places. The mineral sources from which they find their way into ground or surface waters are not known in all cases. Their chemical properties make their removal from water difficult, especially since the amount necessary to produce mottled enamel is very low, but progress is being reported which

may later make possible the removal of fluorides from waters on a basis practical for water-treatment plants.

For the present, however, the best hope concerning mottled enamel lies in avoiding waters high in fluorides. Now that the cause is known, it is possible to state with assurance that the defect can be completely prevented by change to a drinking water supply containing little or no fluoride. In an afflicted community this should be done for all children who do not as yet have all their permanent teeth, and should include not only their drinking water but also that used in cooking their food. If a change is made, benefit will result to all teeth the enamel of which is not yet formed, but the teeth already marred, even though not yet erupted, will unfortunately not be cured. If water from a certain stratum is high in fluorides, it is usually necessary in that community to resort to water from a different stratum or to cistern water. In the light of our present knowledge, too high a fluoride content in a proposed water supply is considered by the Kansas State Board of Health as grounds for withholding approval of the supply, because of the irreparable damage to children using it.

Besides examining municipal water supplies, the State Board of Health is interested in locating cases of mottled enamel resulting from the use of private well waters. On private wells in Kansas which are suspected of causing mottled enamel, fluoride determinations will be made free of charge if a pint sample of the water and a history of the mottled enamel cases associated with it are sent to the State Water Laboratory at Lawrence, by a physician or a dentist. The coöperation of members of the Kansas Academy of Science in locating cases of mottled enamel in this state will be greatly appreciated.

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A Study of the Reliability of Examination Marks in General Chemistry: II. An Objective Examination

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A wide variation in grades when different instructors of general chemistry graded the same essay-type examination paper in first-semester general chemistry was previously noted by us.[2] A number of those instructors suggested that the type of examination was responsible for the variation. In order to investigate the influence of the type of examination on the variation in grading this study was undertaken. A mimeographed objective examination paper, question and answer, was submitted for grading to one hundred instructors of general chemistry. Fifty graded lists were returned.

The objective examination is diveded into four parts: A, problems on solutions; B, oxidation and reduction reactions; C and D, a completion and a true-false test, respectively, of descriptive and theoretical work. There are 3 parts in A, 2 in B, 5 in C and 20 in D—a total of 30 questions. The weighting of parts A, B, C and D was not stated and introduced the first variation in grading. Seventeen persons gave equal weight (25 per cent) to each part; seven gave A a value of 15, B of 10, C of 25 and D of 50 per cent; three gave A, B and C each a value of 20 and D of 40 per cent.

Although a study of the grades given by each instructor on each of the thirty questions which make up the examination doubtless might present opportunities for interesting deductions, nevertheless the consideration of the grading of the individual parts is believed to be of more detail than value and is omitted. However, the grading of the four divisions A, B, C and D offers sufficient variation to be taken up in some detail.

Inasmuch as part A consists of 3 problems of which 2 solutions are wrong and 1 is right, the grading would be expected to be fairly consistent and fixed. However, contrary to instructions no calculations of any kind are shown and the variation in grades from 1.6 to 8.7 is not altogether unexpected. As may be seen there is a strong centering of the grades around the predicted 30 per cent with a scattering equally above and below.

Part B is composed by 2 parts, each an equation for an oxidation-reduction reaction to be balanced by a specifically named method. To expedite the attack on the questions there is an indication that the oxidation and the reduction be set down as separate formulations. In the first equation, the oxidation is correctly stated, but not so the reduction. In the second equation, the element copper is to be oxidized as the sulfur is reduced. The student has confused the classification of these reactions as well as misstated them. Therefore it is of interest to note that the grades given on part B range from zero to 5.2.

The completion test, part C, is composed of five parts, 3 of which relate to descriptive chemistry and 2 to theoretical chemistry. In the first question no specific numbers of uses of sulfur dioxide is required. The answer to the second question reveals only that the student knew the empirical formula for

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2. Homan and Hodge, J. Chem. Educ., 8, 2071 (1931).

the two substances named. One of the names of the formulæ given in the third question can be considered correct from the point of view of beginning chemistry. The answer to the fifth question is garbled, but recognizable. We may see that the grades express valuations from 2.0 to 8.8, and that there is but one peak in the grade distribution with a goodly scattering of grades between the above-named limits.

Part D, the true-false test, consists of 20 statements a number of which were poorly stated and many of which were cause for dissention among graders. Grades were given as low as 4 and as high as perfect.

The distribution of the total scores on the examination is given in Table 1. Here the mode is 61, the median, 48 and the average 47.6 per cent. The range of grades from 28 to 81 per cent includes 54 integers possible, of which 27 were given. In the grading of the "conventional" examination referred to above [1] the grades given ranged from 22 to 57 per cent, including 36 possible grades, of which 29 were given.

TABLE 1

Grade	*Cases*	*Grade*	*Cases*	*Grade*	*Cases*
28	1	42	0	59	0
28.5	1	43	3	60	2
29	0	44	0	60.7	1
30	1	45	0	61	4
31	0	46	1	62	0
32	1	47	2	63	0
33	1	48	2	64	0
34	1	49	2	65	2
34.1	1	50	3	—	—
35	3	51	1	—	—
36	0	52	2	—	—
37	2	53	0	75	1
37.5	1	54	2	—	—
37.7	1	55	1	—	—
38	2	55.41	1	—	—
39	0	56	1	81	1
40	1	57	2		
41	0	58	0		

A number of comments accompanied the graded lists, some severely critical, others expressions of interest. Typographical errors and ambiguities were scored by a number. A consensus of opinion revealed the belief that this type of examination would bring out maximum variation in grading. The evaluation of the four parts of the examination was also the subject of many notations, the sense of which may be summed up in the statement that the professor giving the examination should set the relative values. One pointed out that in his estimation the chief factor producing variation was the ignorance of the graders concerning both the material presented and also its method of presentation.

In one college, three instructors independently gave the remarkably concurrent grades of 50, 55 and 55 per cent. In another college, however, four instructors reported 46, 50, 57 and 81 per cent, leading the head of the department to state that "apparently there is sufficient variation to substantiate your suspicions." The *coup de grace* came in the statement of a professor in these words, "It is my opinion that such a test as this could serve only the purpose of fulfilling the requirement of being so devised that one's wife could do the grading."

Nitro Compounds as Oxidizing Agents: II

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INTRODUCTION

This is the second of a series of papers concerning the action of sodium benzylate upon aromatic nitro compounds. A study was made of the oxidation and reduction products and the quantities of each obtained by varying the length of time, the alkalinity of the reaction mixture, and the amount of oxidizing agent used. In each case the amount of benzyl alcohol used was in excess of the calculated quantity necessary for complete reduction of the nitro compound. Results of a series of experiments can best be shown by means of Table I. The temperature of the reaction, alkalinity of the mixture, and time of reaction are listed; together with the yields of reduced compound and benzoic acid. Benzaldehyde was detected in experiments carried out at low temperatures and for a short period of time. In no case did the reduction proceed as far as the primary amine.

EXPERIMENTAL PART

1. *p, p′-Azobenzoic acid.* Ten grams of powdered sodium hydroxide and 10 c. c. benzyl alcohol were placed in a three-necked, round-bottomed flask equipped with a mechanical stirrer and reflux condenser. The mixture was stirred until the reaction was complete, and then 100 c. c. xylene was added. The whole was refluxed several minutes and cooled to room temperature. Ten grams of powdered p-nitro-benzoic acid were added and the mass allowed to react at room temperature for one hour. It was heated to 100° C. by means of a water-bath for one hour, and then to 125° C. for one hour by means of an oil-bath, and finally to a temperature of 150° C. for three hours. The mixture became dark green in color and changed to a reddish-orange as the reaction proceeded. After cooling, the reaction mixture was steam distilled to remove the xylene. The clear, red solution was acidified with hydrochloric acid from which the benzoic acid was removed by repeated extractions with hot water. The extractions were allowed to cool, and the benzoic acid was filtered, dried, and weighed. A correction was made for dissolved benzoic acid. (0.3 g. per 100 c. c. water.) The red amorphorus powder was further purified by dissolving it in dilute ammonium hydroxide and reprecipitating it with hydrochloric acid. It was a red substance without crystalline structure, insoluble in all the usual organic solvents and corresponded in its properties to the compound described by Ruchenbach and Beilstein (*1*) as p, p′-azo benzoic acid.

2. *m, m′-Azobenzoic acid.* m-Nitro-benzoic acid was treated in the manner described for the para isomer. A white, amorphorus powder was obtained, which was insoluble in all the usual organic solvents and corresponded to the azo derivative, as described by Strecker (*2*).

3. *o, o′-Azobenzoic acid.* The ortho isomer was treated in the manner described for the para derivative. The color change was from white to a light yellow toward the end of the heating period. The amorphorus compound was

recrystallized from alcohol in yellow needles, which decomposed at 237° C. It corresponded to the compound obtained by Greiss (*3*).

4. *p, p'-Dibromo-azoxybenzene.* Four grams of powdered sodium hydroxide and 5 c.c. benzyl alcohol were placed in the flask previously described and 20 c.c. xylene added after the initial reaction was complete. The mixture was refluxed several minutes and cooled to 20° C. Five grams of p-bromnitrobenzene were dissolved in 30 c.c. xylene and added drop-wise. After standing for one hour at room temperature, the mixture became dark brown in color. It was heated to 100° C. for one hour, the color changing to a deep yellow. The temperature was increased to 125° C. for one hour and then to 150° C. for one hour. By this time the reaction mixture had become a golden yellow color. The temperature was increased to 175° C. for an additional hour without any color change. After cooling, the xylene was removed by steam-distillation, the reduced compound separating as a yellow solid. It was collected and crystallized from glacial acetic acid, giving small, golden-yellow plates, with a melting point of 174° C. Zechmeister and Rom (*4*) report the melting point as 172°, whereas Busch and Schulz (*5*) find 175° C. Analysis calculated for $C_{12}H_8ON_2Br_2$: Br, 44.94 per cent. Found, 44.92 per cent.

5. *m, m'-Dibromo-azobenzene.* m-Nitro-bromobenzene was treated as described for the para isomer, except the maximum temperature reached was 150° C. The reaction mass became dark brown at room temperature, but changed to yellow as the heating was increased. The crude yellow product was crystallized from glacial acetic acid in the form of small, golden-yellow plates, with a melting point of 108-109° C. Zechmeister and Rom (*4*) list the melting point at 111°, with Busch and Schulz (*5*) giving 107-109°. Analysis calculated for $C_{12}H_8ON_2Br_2$: Br, 44.94 per cent. Found: Br, 45.03 per cent.

6. *o, o'-Dibromo-azoxybenzene.* Three grams of sodium hydroxide and 6 c.c. benzyl alcohol were used in this case. Thirty-five c. c. toluene was used as the solvent for the sodium benzylate and 15 c.c. to dissolve the nitro compound. The mixture was allowed to react at room temperature for one hour and at 100° C. for seven hours. The crude product was crystallized from alcohol and melted at 112-113° C. Zechmeister and Rom (*4*) report the melting point to be 112° C. Analysis Calculated for $C_{12}H_8ON_2Br_2$: Br, 44.94 per cent. Found: Br, 44.96 per cent.

7. *m, m'-Diamino-azoxybenzene.* Five grams of powdered sodium hydroxide was placed in the flask previously described and 5 c.c. benzyl alcohol added. After the initial reaction was complete, 50 c.c. xylene was added and treated as indicated in an earlier part of this paper. Five grams of powdered m-nitraniline was added to the cooled mixture in small portions. The mixture was allowed to react one hour at room temperature, one hour at 100° C., and finally, for three hours at 125° C. The reaction mixture changed from yellow to dark brown and yielded a dark-brown tar-like substance upon removal of the solvent. This was purified by solution in dilute hydrochloric acid, boiling with norite, filtering and precipitating by addition of ammonium hydroxide. The yellow precipitate was collected and recrystallized from a large quantity of hot water, producing long, yellow needles, melting at 147-148° C. Meldola and Andrews (*6*) report the melting point at the same temperature.

TABLE I. This table summarizes representative results obtained by varying time, temperature, and alkalinity in the reduction of certain nitro compounds.

Ex. No.	Isomer	cc. alc.	Grams NaOH	Time in hours at 20°	100°	125°	150°	175°	Grams Azo Comp.	Grams Benzoic Acid
				NITRO BENZOIC ACIDS						
72	p-	5.0	5.0	1	1	3	-	-	3.4	3.6
73	p-	5.0	3.0	1	1	1	2	-	3.0	3.0
74	p-	5.0	5.0	5	-	-	-	-	0.0	0.0
75*	p-	10.0	10.0	1	1	1	3	-	8.8	9.6
76	m-	5.0	5.0	1	1	1	2	-	3.6	3.6
77	m-	5.0	3.0	1	1	1	2	-	2.4	2.5
78*	m-	10.0	10.0	1	1	1	3	-	8.0	8.1
79	o-	5.0	5.0	1	1	1	1	-	4.1	3.7
80	o-	5.0	5.0	1	1	3	-	-	4.2	4.3
81*	o-	10.0	10.0	1	1	1	3	-	8.3	8.8
				NITRO BROMOBENZENES						
46	p-	4.0	3.0	1	5	-	-	-	4.8	2.4
91	p-	5.0	5.0	1	1	4	-	-	4.7	3.8
92	p-	6.0	8.0	1	6	-	-	-	4.3	3.9
93	p-	4.0	5.0	1	1	1	1	1	4.8	3.7
94	m-	4.0	5.0	1	1	1	1	1	4.8	3.8
87	m-	8.0	6.0	1	1	1	1	-	4.3	4.7
86	m-	8.0	6.0	1	6	-	-	-	4.4	5.0
85	m-	3.0	5.0	1	1	3	-	-	4.3	3.6
84	o-	3.0	5.0	1	1	1	1	-	3.2	3.6
58	o-	2.0	4.0	1	4	-	-	-	2.3	3.0
65	o-	3.0	6.0	1	7	-	-	-	2.5	3.6
68	o-	3.0	6.0	1	1	2	-	-	2.0	2.0
				NITRANILINES						
105	p-	2.0	5.0	1	1	2	-	-	1.1	1.7
96	p-	4.0	6.0	1	1	2	-	-	4.0	4.3
24	p-	5.0	5.0	1	1	1	1	-	2.5	3.1
22	p-	4.0	5.0	1	1	1	1	-	2.7	2.8
19	p-	3.0	4.0	1	2	-	-	-	1.9	1.5
17	p-	2.0	4.0	1	4	-	-	-	2.1	2.0
23	m-	5.0	5.0	1	1	3	-	-	4.0	4.6
50	m-	8.0	6.0	1	1	1	1	-	4.3	4.7
88	m-	4.0	5.0	1	1	4	-	-	4.0	3.6
89	m-	5.0	5.0	1	6	-	-	-	3.6	3.1
90	m-	3.0	5.0	1	1	1	1	-	3.5	2.9
98	m-	6.0	5.0	1	1	1	3	-	4.0	4.8

8. *Experiments with p-Nitraniline.* p-Nitraniline was treated in the same general manner as outlined for the meta isomer, but the reduction product consisted of a series of compounds. A small amount of substance, melting at 142-143° C., could be isolated and corresponded to p, p′-diamino-hydrozo-benzene, (7) which melts at 145° C. Also a small amount of a compound, melting at 233-237° C., could be isolated and this compound possessed the properties of p, p′-diamino-azoxybenzene as outlined by Mixter (*9*). Satisfactory experimental conditions could not be worked out that would produce but one product. It was also found difficult to repeat previously performed experiments. Experiments with para-nitro-acetanilide were conducted in hopes of being able to isolate a single product, but in each case the aceto group was saponified and products similar to those obtained with p-nitraniline were isolated and identified.

9. *Experiments with o-Nitraniline.* Various experimental conditions were tried, but in all cases considerable decomposition took place and the only substance that could be separated was a red oil, which could not be crystallized nor could it be converted into a solid derivative.

In the experiments described in the table on page 137, five (5) (or in three cases indicated by an asterisk, 10) grams of the nitro compound were used. Ten (10) c.c. of xylene were used as a solvent for each gram of the nitro compound.

SUMMARY

1. Aromatic nitro compounds have been found to oxidize benzyl alcohol in nonaqueous alkaline solutions to benzoic acid, with benzaldehyde as an intermediate in the process.

2. In no case was the nitro compound found to be reduced to the corresponding amine, although azoxy, azo and hydrazo derivatives were isolated and identified.

3. The yield of benzoic acid was found to be determined by the alkalinity, temperature, and nature of the nitro compound.

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A Summary of Published Information About Pharaoh's Ant, With Observations on the Species in Kansas[1]

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Pharaoh's ant[2] (*Monomorium pharaonis* Linn) is the smallest, reddish-brown ant, the most frequent ant invader, and the most difficult ant to eradicate of all species of ants occurring in Kansas homes. Several local invasions have proved to be very difficult to eradicate. The question arose as to whether there had been suggested any good control methods for this species other than those being used against them. In order to have available the widely scattered information about the life history, habits and control of this ant, it was decided to prepare a summary of the important available published accounts. It is believed that this paper includes all information of importance which has been published to date on this ant. Little attempt has been made to quote the author first suggesting any point of life history or control.

NAMES OF THIS ANT, ITS ORIGIN AND DISTRIBUTION

This species of ant has been variously called the "yellow ant" and the "little red ant." The term "yellow ant" is, however, better adapted to the much larger, recent household ant pest, *Lasius interjectus* Mayr. "Pharaoh's ant" is the official common name for *Monomorium pharaonis* (Linn).

Riley (1889) stated that the "red ant" unquestionably came from Europe and has become cosmopolitan. He said that Linnæus gave the species name "Pharaoh's ant" to it on account of "a defective knowledge of scripture, imagining that ants formed one of the plagues of Egypt in the time of Pharaoh, whereas the only entomological plagues mentioned were lice, flies and locusts." Lintner (1895) said that Linnæus described the European insect in 1767 under the name of *Formica pharaonis* and gave its habitat as Egypt.

Marlatt (1916) said that "the little red ant . . . is the best known house species. It was originally a soil ant, nesting out of doors in warm countries, and doubtless continues this habit in the tropics of both hemispheres."

Pharaoh's ant is a widely distributed species in the world, and can now be found in every town of any size or commercial importance in the United States. Professor Dean stated verbally that this ant has been a pest in Kansas for at least fifty years. Hayes (1925) pointed out that this species was often "confused with *Solenopsis molesta* Say (thief ant) both of which infest houses and are spoken of as "red ant."

Severin (1920) stated that the "tiny thief ant has been found to nest in buildings occasionally in South Dakota. The workers are orange colored and are the smallest of all our house ants, for they measure but a little more than one thirty-second of an inch in length. Pharaoh's ant can be distinguished from all of our house ants in that the workers measure about one sixteenth of an inch in length and in that they are light yellow is color. Wherever the thief ant was discovered in homes and stores in South Dakota, it was

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1. Contribution No. 425, Department of Entomology, Kansas State College.

2. Dr. M. R. Smith has identified this species from local infestations.

present in immense numbers and swarmed over such food as meat, bacon, lard, grease, etc."

FEEDING HABITS AND FORAGING

Lintner (1895) said that this pest is "attracted to almost everything in the house; sweets, greases, dead insects, even shoe polish and bath sponges have been reported as attractive to them. They will also damage collections of insects and are pests in breeding cages for insects. They are very persistent in the search for food even when closely covered, and their small size makes it difficult to exclude them . . . Very little food will maintain a large host of them . . . . Freshly killed insects, as cockroaches, also greasy bones and masses of sweets, appear to be particularly attractive."

Riley (1889) stated that this insect was a nuisance, not from the actual loss by consuming food products, "but from its inordinate faculty of getting into things. . . . A house infested with these creatures is almost uninhabitable."

Herrick (1914) stated that it "literally swarms in houses, and because of its small size, gets into everything that is not almost hermetically sealed. Hardly any household food products come amiss to the red ants. They are especially fond of sugar, sirups, fruit juices, jellies, cakes, fruit pies, and the like. Workers inform the colony when some food is located and soon numbers of ants swarm over the food and it appears that no matter how many are killed, an equal number comes to take the places of those destroyed and as long as the queens are allowed to live on undisturbed the workers may continue to come."

Smith (1928) classified house-infesting species of ants under two groups according to food preference: Sweet-eating species and grease-eating species. He placed Pharaoh's ant in the grease-eating group. It has been the writer's observation that this classification is correct. While Pharaoh's ant eats some sweets, its preference is fats.

Forbes (1920) stated that while this species frequently infested kitchens and pantries, it had been reported once as "seriously injuring corn by gnawing the blades when they were but a few inches high for the purpose of drinking the sap which flows from the wounds. In 1850 it was so numerous and active in some New York corn fields as to threaten to destroy every blade of corn in them."

Garman (1917) stated that this species gets "into sugar bowls, upon cakes and other pastry, into sirup, and, in fact, almost anything edible. . . . It is not a reflection upon anyone's carefulness that these persistent creatures now and then invade a dwelling and refuse to be routed out."

Zappe (1918) said that while the favorite place was the "bath rooms where they could be seen drinking water and running along the tile floor, there were ants in every room of the house; a few could be found on tables, writing desks, among clean clothing in bureaus, on the floors, walls, etc." These ants exhibited these same habits in a Manhattan, Kan., hotel. They were most numerous around sinks and bathrooms, where they sought moisture, but they also occurred among clean bed linen, towels, and even in sewing baskets.

Lintner (1895) pointed out that "few people like to pick them out of food or to eat from plates over which they have been running, or to see them on table linen, yet, when abundant, it is almost impossible to keep them away. Though not generally known, a large number of these insects in food can impart an agreeable acid flavor."

Riley (1889) and Herrick (1914) stated that this ant attacked and killed bedbugs in homes. Under certain conditions they were observed to attack white grubs in soil. Hayes (1916) reported it as a predacious enemy of the larva of the corn bill bug. Pierce (1912) listed Pharaoh's ant as one of the most important enemies of the cotton boll weevil, and stated that the ant was abundant in the cotton fields in certain sections.

THE NEST

Riley (1889) said that they formed "their nests in almost any secluded spot, between the walls or under the floors or behind the base-boards, or among trash in some old box or trunk, or in the lawn or garden walk just outside the door. In each of these nests several females will be found, each laying her hundreds of eggs and attended by a retinue of workers caring for the larvæ and starting out from dawn till dawn on foraging expeditions in long single files."

Smith (1907) said that this species made its "nests behind the plaster, wainscoting or base-boards, behind mantles, under hearthstones and, in fact, wherever there are cavities with external openings. As the insects are so small the narrowest crack or opening will serve and their nests are as a rule beyond reach."

Severin (1920) mentioned that the little red ant nested "inside of heated buildings such as homes, stores, greenhouses, etc."

Observations in Kansas indicate that the nests are made either inside of buildings, as in small cracks or crevices, behind base-boards, wainscoting, in cement or stone walls, on foundation walls, between flooring or in furniture, or outside of buildings, as under stones, heaps of trash and in boxes.

THE COLONY AND CASTES

Pharaoh's ant, like other ants, passes through four stages—egg, larva, pupa and adult. The adults are divided into the neuter worker caste and the true sexes, males and females or kings and queens. The workers do all the work of the colony, such as foraging for food, taking care of the eggs, larvæ and pupæ. The two sexes are the reproductive forms, the queens living a long time and laying many eggs. In heated houses this species probably breeds through the entire year.

Howard and Marlatt (1902) stated that the colony consisted during most of the season "almost exclusively of workers with one or more perfect, wingless females. Winged males and females are produced during the summer and almost immediately take their nuptial flight. The males soon perish, and the females shortly afterwards tear off their own wings, which are but feebly attached, and set about the establishment of new colonies. The eggs, which are produced in extraordinary numbers by the usually solitary queen mother, are very minute, oval, whitish objects, and are cared for by the workers, the young larvæ being fed in very much the same way as the colonies of the beehive. The so-called ant eggs, in the popular conception, are not eggs at all, but the white larvæ and pupæ and, if of females and males, are much larger than the workers and many times larger than the true eggs."

Flint (1922) said, "each nest contains two or three queens and the rate of reproduction is very high, so that a few months after a colony is established it may contain several hundred workers."

Bellevoye (1889) put out bits of liver on pieces of paper in a cupboard in his home in Rheims and three or four times a day shook the paper in benzine. In this way in 6 weeks he captured 577 females, only 14 of which were winged, 239 males, and about 349,500 workers (computed by weight) and the supply, presumably from one colony, was not exhausted.

He pointed out further that mating took place subterraneously, and that the males and females continued to live in the same nest, and that the true sexes appeared in France the latter part of September and all of October. Following mating, the females lost their wings, the front ones first, since females were seen with only the hind pair. The males retained their wings, but preferred running to flying.

CONTROL OF PHARAOH'S ANT

The various recommendations for the control of this species can be summarized under seven headings, as follows:

1. Trapping the Ants

Riley (1889) mentioned that "sweetened sponges placed where the ants congregate, collecting them daily and soaking in hot water was the best trap suggested" but that it was "slow and tedious."

Zappe (1918) said that "trapping with a sponge dipped in a sweetened solution, and when full of ants dropping it into hot water, killed many ants, but they soon became suspicious of the sponges, after which very few would venture to go into them."

Garman (1917) stated that a "tin tray covered with grease is an attractive bait for this ant, and can be burned off over a gas jet or coal fire to destroy them."

Smith (1928) suggested for trapping "meat-eating species that the sponges be dipped into grease."

Smith (1907) told how he destroyed the ants which were attacking his collections. He set out a "piece of raw bone" with little adhering scraps of meat and blood near their runs and destroying it when fully covered with the insects. Such bait would become covered in an hour or two, and it was then dumped into the stove and more bait put out. Even the brown paper in which the meat was sent from the butcher was set out, baited with a little meat scraping and crushed into a loose wad." When covered with ants, he lifted the paper without disturbing the ants and dumped it into the fire. "A steady campaign brings about a very rapid reduction, and generally in two or three weeks there is a complete absence of specimens at the baits." He recommended further using "two sugared sponges, one to replace the other while the ants are being washed out of it with hot water. These baits attract the queens and a colony rendered queenless or depleted seriously in numbers either slowly perishes or abandons the place."

The sponges or traps should be treated several times during the first twenty-four hours to destroy the ants, otherwise they will carry considerable food back to the nest. Generally these traps collect the greatest number of ants during this period, especially during the first night.

2. Locating and Destroying the Nest

This is the most logical control method for this species as well as for all the other species of house ants. It is complicated, however, by the difficulties of finding the nest and by the fact that a building may have two or more nests in it at a time.

Ruggles (1932) suggested that "an easy way by which to trace the ants back to their nest is to give them a little granulated sugar and then watch them carry it away." Herrick (1914) suggested baiting black ants with broken pieces of rice, farina or cream of wheat "to trace them to their nests."

Howard and Marlatt (1902) said that "unless the colony of the species can be reached and destroyed all other measures will be of only temporary avail. If in a wall, the inmates may sometimes be reached by injecting bisulphide of carbon or a little kerosene. If under flooring, it may be possible to get at them by taking up a section." Garman (1917) stated that since the species was so difficult to eradicate, it may well be worth while, therefore, to take the pains necessary to locate the nest, even at the expense of taking up flooring or breaking into walls. . . . The nests may be reached by steam, by oils, or by fumes of some sort, so as to destroy all of the occupants."

Riley (1889) said that "our first recommendation is to find the point from which they all come. They may have built the nest in some accessible spot, in which case a little kerosene will end a large part if not all the trouble. If the nest is in the wall or under the floor and taking up a board will not bring it within reach, find the nearest accessible point and devote your energies to killing the ants off as they appear. Where the nests are outside, nothing is easier than to find them and to destroy the inhabitants with kerosene or bisulphide of carbon. . . . The ants are peculiarly susceptible to the action of pyrethrum in any form—. Persia or Dalmatian powder or Buhach, and a free and persistent use of this powder will accomplish much."

"An oil can or syringe may be used to force carbon bisulphide, kerosene or gasoline into the nest . . .," said Hungerford. (1924.)

Washburn (1907) found that the fumes of carbon bisulphide penetrated to all parts of the house and was very disagreeable to the family. He found kerosene applied with a syringe just as effective, but less objectionable. Ants not hit would soon gather, seek another crevice and form another colony. Various "ant cures," as "ant sugar," pennyroyal, tartaric and syrup bait were not successful. Fumigation with HCN was planned, when the colony disappeared.

Lintner (1895) recommended hot water to destroy this pest.

Hungerford (1924) mentioned destruction of ant nests with calcium cyanide. This material has been used in Kansas against Pharaoh's ant with quite as good results in destroying nests as carbon bisulphide. When the nests are located, a small quantity of calcium cyanide, either Cyanogas "A" dust or "Calcyanide" is blown into the nest or into cracks where the ants hide. The gas from these materials is quickly fatal to all insects, but in such small amounts is unlikely to cause any ill effects to human beings. There is no fire hazard in their use and gas may be given off for several hours, so the material is effective for a longer period.

Injecting gasoline or benzine into the ant nests has been repeatedly recommended. Either will quickly kill all the ants made wet by these liquids, but

the writer and his associates believe that the fire hazard in using these materials is too great. Gasoline is so familiar to everyone that it is used carelessly.

3. Poisoning

The most frequent recommendation for ant control is the use of a poisoned syrup. Experience indicates that the sodium arsenite syrup is less successful with this species than against all the other household ant species. It does, however, have some value. The writer has had best success with tartar emetic and thallium sulphate.

Ant poisons, especially the syrups, do not destroy the colony immediately, but the poisoned material is carried back to the nest by the workers and there fed to the larvæ. The colony should be noticeably smaller in from a day to a week after the baits are exposed.

Smith (1928) stated that for the grease-eating species of ants, which includes Pharaoh's ant, "probably the best control is obtained by rubbing powdered tartar emetic on greasy bones or on strips of raw or cooked meat and placing this bait in cans." He suggested using baking powder cans, crimping the tin at the top on opposite sides to provide an entrance for the ants beneath the lid.

Marlatt (1916) recommended a formula for this species as follows: "One pound of sugar dissolved in 1 quart of water, to which should be added 125 grains of arsenate of soda. Boil and strain, and on cooling is to be used with sponges. A small amount of honey may be added to increase the attractiveness." Zappe (1918) used this formula with sponges on shallow dishes and found that it was soon discovered by the ants and large numbers, including queens, were seen feeding on the bait. A second batch of bait proved to be too thick. The sugar content was reduced to ½ pound and it was found that the syrup did not harden nor dry so quickly and that the ants ate it more readily.

He also made a poisoned bait of finely chopped beef liver, 2 ounces, potassium cyanide, 150 grains, dissolved in water, and mixing with the liver. There were not sufficient ants to provide a fair test of this bait.

Herrick (1914) stated that "tartar emetic mixed with four or five times its volume of syrup and placed in shallow dishes is an effective remedy against house ants. It may also be mixed at the rate of 1 part tartar emetic, 10 parts sugar, and 100 parts water. This poisonous mixture exposed in shallow containers where ants are plentiful is said to be effective."

Flint (1922) said that "these ants may be poisoned by baiting with small pieces of bacon rind into which a small amount of tartar emetic has been worked. Remember that the material is poisonous and must not be placed where children or pets will have access to it." Hungerford (1924) recommended treating "bacon rind or grease with tartar emetic, mixing it 1 part to 20 of grease."

Popenoe (1926), in writing on the properties of thallium sulphate, said that "the small red ant, a species which arsenic sirups fail to control, has been exterminated in a number of houses and apartments within periods of three weeks to a month by the application of a sirup prepared by the writer and consisting of 1 pint water, 1 pound sugar, 27 grains thallium sulphate and 3 ounces honey, the whole being brought to a boil and thoroughly stirred. The ants continue to consume this syrup until the entire colony is destroyed, the

thallium appearing to act as a slow cumulative poison, the effects of which are apparent in observable colonies by the considerable numbers of dead queens, larvæ and workers discarded daily."[3]

Cotton and Ellington (1930) coated pill boxes with paraffin and cut away "four small sections from the inner circular collar over which the top or cap of the pill box fits." In use the cover is raised sufficiently to expose the four small openings to provide points of entrance of the ants to the poisoned syrup. The cap keeps out dust and makes poisoning of pets unlikely. The containers are small and inconspicuous. The boxes were filled about two thirds full of small pieces of blotting paper. A little poisoned syrup was poured over the blotting paper. The thallium sulphate-poisoned syrup was used in the boxes. It was very effective and infestations were wiped out in a few days.

Flint (1922) said that "for poisoning these ants, a syrup containing a small percentage of poison should be used. If a strong poison is used, the ants will detect it and refuse to feed upon it. Ordinary sugar syrup is not particularly attractive to them. A number of syrups have been tried in which meat products and meat extracts have been used, but these do not seem to be especially attractive. The only syrup found effective against these ants is one made in the following manner. Boil together the following materials for thirty minutes: granulated sugar, 4 pounds; water, 4 pints; tartaric acid (crystallized), 3 grams; benzoate of soda, 3 grams. Dissolve sodium arsenite in hot water in the following proportion: Sodium arsenite (CP), ¼ ounce; hot water, 3 fluid grams.[4]

"When the above solutions have cooled, add the second to the first and stir well. Then add two thirds of a pound of strained honey to the resulting syrup and mix thoroughly.

"The ingredients for this syrup may be purchased from any drug store and should be carefully weighed by the druggist. Mix carefully according to the directions given.

"While this bait is somewhat difficult to make, it is generally effective against these ants. Small pieces of sponge should be thoroughly soaked in the syrup and placed in tin boxes, the lids of which have had several holes punched in them in order to give the ants ready access to the bait. A few strands of excelsior may be substituted for the sponge. Several of these boxes should be placed in pantries, in closets and other parts of the house where the ants are numerous. The bait should be renewed from time to time, and if the ants cease feeding in any one spot, the location of the tins should be changed. It will be two or three weeks after this bait is put out before the effect on the ants will be noticeable, as the amount of the poison contained is not sufficient to kill at once."

Davis (1928) stated that "poisons were useful in ant destruction and should be used if the nests cannot be located." He recommended a poison made by "mixing a level teaspoonful of tartar emetic with about five times this amount of syrup or diluted honey, or one-fourth ounce of the tartar emetic and two and one-half of sugar dissolved in one and one-half pints of water. The poisoned liquid is used in saucers and it is best to have a piece of sponge or

3. "Lethelin" is a proprietary compound for sale at stores, which at this writing contains thallium sulphate.

4. "Antrol," another proprietary compound, makes use of sodium arsenite.

excelsior in the bait to enable the ants to get to the poison to a better advantage. Or better, small pieces of sponge or excelsior may be soaked in the syrup and placed in tin boxes, the lids of which have had several holes punched in them, and these placed about the house where ants are numerous. Small pieces of bacon rind or chipped beef or grease into which a small amount of tartar emetic has been worked is more effective for some species of ants than is a sweetened solution."

Gibson (1916) told of very satisfactory control of the common carpenter ant in a home by the use of sodium fluoride, which he applied by means of a small puffer or dust gun. The powder was dusted into the openings between the beam and the roof, as also into their openings and cracks daily. In two days the ants were absent. He had equally good results with the common shed-builder ant with one application.

Sodium fluoride is an excellent stomach poison for ants, the writer and his associates have found. It serves chiefly as a repellent, driving not only the foragers out of a cupboard, but sometimes either killing out the colony or forcing it to move.

Dusting sodium fluoride in cupboards or where ants must walk in it, has been recommended by Guyton (1926) and others. "This compound kills the ants by contact."

4. Removal of the Attracting Substances

Materials sought by the ants serve to attract the foragers and a colony may be established nearby, particularly if the food supply is continuous and ample. Shaking crumbs from the table cloth on the back porch or out the back door provides on attraction for ants. Sometimes useless food materials such as some old bread, meat rinds, spilled sugar, cakes, pie crust, and many others pushed back in cupboards and forgotten serve to attract them. These can be discarded without loss. Many foods can be advantageously kept in tight containers and others in refrigerators with tight-fitting rubber-sealed doors to prevent ant attraction. Many of the old ice boxes are not tight and occasionally this species enters through cracks or doors to attack food within. The garbage can kept on the back porch attracts them to the house.

This species of ant sometimes becomes a pest in offices. A common source of attraction is crumbs dropped from lunches and food materials kept in desks, drawers or food scraps thrown in wastebaskets.

5. Repellents

Numerous chemicals and other ill-smelling or odoriferous materials have been recommended for the control of this species. Repellents do not destroy the ants, but merely drive them elsewhere where they continue to be a problem. The use of repellents is, therefore, not ordinarily advised. As temporary expedients under certain conditions, they have a limited field of usefulness. Not all the materials listed under this heading are properly classified as repellents.

Howard and Marlatt (1902) recorded the incident of repelling ants from a pantry by "placing gum camphor, either free or wrapped loosely in paper, in pantry, sugar barrel or other situations infested with ants. The odor of the

camphor seems to be very distasteful to them and they promptly cease to infest the premises."

Washburn (1918) said that "pantry shelves painted with a saturated solution of alum appear to defy these insects."

Herrick (1914) stated that "naphthalene flakes has also proved an efficient repellent against ants. The material is simply scattered about on the shelves and in the corners frequented by the ants."

Zappe (1918) said that naphthalene flakes had but little effect, being "only local, merely driving them out of the room where it was used; the family objected to the use of naphthalene."

Smith (1907) said that "ants dislike the odor of carbolic acid and of naphthalene, and they can usually be kept away from substances that it is desirable to protect in infested localities."

Garman (1917) stated that "insect powder should be strewn about shelves and floors at frequent intervals when the ants are about. . . . Coal oil, whenever its use is practicable, is the most effective insecticide known. If it can be sprinkled across the routes taken by the ants it is a barrier across which they dare not pass. A touch of the oil on their bodies is fatal, sooner or later."

Smith (1928) said that he had "not found borax, red pepper, chalk, peppermint leaves, salt, or many of the other commonly used household remedies of any value whatever," and does not recommend their use.

Herrick (1914) mentioned the well-known expedient so widely used in the tropics and the southern part of the United States of setting the table legs in a cup of oil, kerosene or similar material to keep the ants from crawling up the table legs. Ordinary cotton tape treated with corrosive sublimate wound around the legs of a table is an effectual barrier against this species. Tape prepared in this manner can be purchased, at least in southern cities, as "ant tape." Herrick gives directions for preparing this tape.

Garman (1917) stated that "saturating strips of cotton cloth, or of cotton tape treated with substances offensive to ants, have been found very useful as a means of keeping ants from ascending the legs of tables, sideboards and the like. Turpentine, coal-oil, and oil of citronella are effective on these tapes and can be used with safety in almost any part of a dwelling . . . of the three, oil of citronella is to be preferred." He then tells how to make the well-known corrosive sublimate tape and adds, "It has no perceptible odor. The fluid and cloth are poisonous, so must be handled at all times with caution, the tape finally burned. The substance is corrosive to metals also, and must not be brought in contact with them for any length of time. Scissors used to cut the tape should be washed carefully, as should the hands."

Hungerford (1924) stated that those objecting to the appearance of taped furniture may paint the following mixture upon table legs, etc.: Corrosive sublimate, 20 grams, dissolved in 60 c.c. ethyl alcohol to which is then added 30 grains of orange shellac. This dries perfectly hard in a few minutes and is absolutely waterproof. It is, therefore, safer to use than the tape and can be used on the supports of tables, beehives, and the like out of doors."

Smith (1928) said that "many ant powders are found on the market at present, most of which contain pyrethrum, sodium fluoride and materials of a similar mixture. Some of these when placed in direct contact with the ants

may kill them immediately if the material is fresh. The powders also exert a repellent effect towards the ants for a few hours or a day, but after this time lose their strength and are not effective. Only in cases where the ants are causing considerable trouble and the housekeeper wants immediate relief, is the application of these powders to be recommended.

6. General Fumigation of the House

Fumigation with hydrocyanic gas of a house or building infested with these ants should be undertaken, usually, only as a last resort. It is useful when the colonies cannot be found nor eradicated by local treatment or where it is desired to combine control of ants with the control of some other household pest such as clothes moths or bed bugs. It would be necessary to fumigate the basement with a heavy charge for the poison gas to reach colonies between the floor and subfloor or in the partitions.

Whitmarsh (1912) stated that "fumigation with hydrocyanic gas is advisable in old and badly infested houses, especially for those forms which build their nests behind walls, under flooring, in timbers and such places."

Washburn (1918) stated that he had "destroyed them in a house from which the owners were absent by fumigation with hydrocyanic acid gas."

7. Persistence and Careful Watching Necesssary

Experience has shown that scarcely any of the control measures mentioned may be expected to eradicate an infestation with one application. It is necessary to repeat the measures until the ants are either destroyed or forced to leave. One should watch closely following cessation of treatment for their return and not allow them to increase their colonies to any extent before applying further remedies.

This species of ant, as well as most of the others, appears to discern when the colony is being persecuted. "The intelligence of the danger or disaster seems to be rapidly communicated from one to another and safer quarters are sought by the colony."

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Vertebrate Fossils from McPherson Equus Beds

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This report is supplementary to a report by H. H. Nininger: Pleistocene Fossils from McPherson County, 1921 to 1924, paper 40 of the 1924 meeting at McPherson. Trans. K. A. S. 31:96; and H. J. Harnly, Vertebrate Fossils From McPherson Equus Beds, Trans. K. A. S. 35:209.

The fossils here reported were found in the gravel on the Hammann farm, 1¼ miles west and 4½ miles north of Conway, and were presented to the McPherson College Museum by John Akers. The determinations have been made by H. H. Lane.

1. Equus leidge:
    A. Complete typical tooth.
    B. Several fragments.
2. Smilodon sp? (Sabre-tooth cat) probably *fatalis* or *nebraskensis*.
    A. A complete cranium.
    B. Three front teeth from different sand pits.
3. Fragmented tusk of Elephas sp?

A Newly Found Locality of Glacial Striæ South of Missouri River

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In August, 1933, an occurrence of bed rock, which has been polished and striated by glacial action, was found by the writer in Kansas City, Mo. The locality is a short distance north and west of Southwest boulevard, and is about two blocks northeast of the Kansas-Missouri boundary. This is south of Kansas and Missouri rivers where but few other occurrences of glacial scratches have been reported either from eastern Kansas (*1*) or from western Missouri (*2*). The striæ are upon the nearly horizontal surface of a portion of the Winterset limestone of the Dennis formation of Pennsylvanian age and are immediately below several feet of drift composed largely of locally derived boulders and pebbles of limestone. This drift was called a "pre-glacial boulder bed" by McCourt (*3*), who must not have seen the evidence of glaciation beneath it. The limestone is in the left-hand valley wall of Turkey creek. The altitude is about 800 feet above sea level and about 80 feet above low-water stage of Missouri river.

The upper surface of the bed rock is highly polished and faintly striated. The surface is irregular, and has the aspects of very minature *roches moutonnees* as it has three or more inches of relief within a horizontal distance of two feet or less. Many faint striæ are present and their direction is south 65 to 70 degrees east (magnetic).

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Gold Prospects in Kansas

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The first mention of gold in the Transactions of the Kansas Academy of Science is found in a lecture delivered by Prof. G. P. Grimsely before the Academy at Topeka, December 29, 1900, entitled "The Mines and Minerals of Kansas." As in other articles found in the Transactions, gold is omitted from the list of minerals. Professor Grimsley offers the following: "Gold and silver, like the prophets of old, we have none; but we do possess mineral in abundance, which is readily exchanged for these precious metals."

Scientifically the professor's statement errs slightly, as gold actually does exist in Kansas, but practicallly, it would have been better for some people had his words gone unchallenged.

In the Transactions of 1901 and 1902, Professor Lovewell, of Washburn College, read papers on the occurrence of gold in the shales of Trego and Ellis counties. Evidently he spent considerable time, over several years, in sampling and assaying this material which had been exposed by the erosion of the Smoky Hill river. Values at least as high as $10 per ton were reported, and his estimated average value of all his samples was between two and three dollars. His work aroused wide interest and attracted engineers and promotors of all kinds to the district. That Professor Lovewell was unintentionally at fault in his methods of sampling or assaying seems borne out by subsequent events.

Waldemar Lingren investigated, for the government, and found encouraging results on only a small portion of his samples. He concluded that the amount of gold did not justify the expectation that it could be found in paying quantities. Doctor Franklin, then at Kansas University, came to the same conclusion. Your society at the time also appointed a committee to investigate, but the writer can find no record of its findings, and it is doubtful if a report was ever returned. There is no record of any reliable mining company ever having operated in the district. Several of the other kind, who made a show of operating, lasted but a short time.

At this time there was considerable criticism of the fire-assay method of determining gold. Interested parties contended that values so obtained were low; that either volatile matter in the ore, or the condition of the gold itself, was sufficient to cause great losses. Unfortunately Professor Lovewell's remarks at the time lent color to these theories, creating a false impression which persists in some quarters even to-day. I wish to make the statement right now that anyone worthy of the name assayer can correctly assay the usual run of ores with ease, and, using well-known precautions, can obtain quite accurate results on any kind of ore.

On account of the rise in the price of gold from $20.60 to $35 an ounce since last summer, search for the yellow metal has been greatly intensified. There may be other places in Kansas where gold mining is being followed, but the scene of our present activity is along the Republican river in the north central part of the state. Assays of a large number of samples from that district received during the past year show value of from nothing up to $0.70 per ton. The average value of all such samples assayed by me is $0.139 per

ton. Assuming these figures are a fair criterion of values, as I believe they are, the possibility of any successful development seems remote.

Assays up to thirty dollars, from this district, have been reported, and such figures, which mean nothing to me, may be the cause of serious loss to those foolish enough to believe them. I think it safe to say that they were either obtained through ignorance or with the deliberate intention of fooling the public.

In the course of my work on these samples I have often heard operators remark that, while the gold is there, it is in some soluble or volatile form which baffles the assayer and makes good recovery by water concentration impossible. To quiet the first statement and obtain further data, the following tests were made:

Ten pounds of a sample assaying $0.175 were panned in a miners pan. That the gold cannot readily be concentrated is shown by the fact that the one pound recovered as concentrate assayed only $0.21. Fifteen pounds of ore were violently agitated by stirring in water, settled one minute, and the turbid water drained off. On evaporating the latter to dryness and assaying the small amount of residue, this was found to contain some five times more gold per ton than the original sample. Samples of the clear water filtered off after agitating the ore gave no qualitative reaction for gold. This eliminates the soluble gold theory. Judging from these results it was thought the gold might be present in the very fine material in these sands. With this in mind a screen test was made on a composite sample made up by thoroughly mixing equal parts of all the samples received, which, as previously stated, averaged about $0.139 in value. The results are shown in the following tabulation:

Screen.	Percentage of total sand.	Gold, ounces per ton.	Value per ton, $35 an ounce gold.
+10	6.3	None	$0.00
+20	4.2	0.0025	0.087
+30	6.6	0.0125	0.438
+40	19.4	0.007	0.245
+60	40.7	0.005	0.175
+80	3.4	None	0.00
+100	6.4	None	0.00
+150	6.8	0.0025	0.087
—150	6.2	None	0.00

Calculated from the percentage and value of each size, the average value of all, by this method, figures $0.157 per ton.

The results of this test show that the values do not occur in the very fine particles, although the turbid wash water from the previous test, on evaporation, gave residues assaying relatively high. My explanation of this apparent inconsistency is that it is due to the presence of "float" gold. Having been transported long distances it is entirely possible that the gold in these sands occurs in extremely thin flakes. A portion of such gold could readily suspend itself temporarily in the wash water and thus account for the values found when this turbid water is evaporated. Its flaky form would also account for its absence in the fine screenings.

These deposits carrying small amounts of gold are of sedimentary origin and were formed during the Tertiary times when eastward flowing streams were bearing disintegrated material from the Rocky Mountains to our Kansas plains. Desirable as this would be, it is extremely improbable that a gold mining industry will ever develop in the state as a result.

The Chert Gravels of Lyon County, Kansas

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The chert of these gravels is impure silica. This silica is evidently derived from an alkaline solution of the mineral occurring abundantly in the water of rivers, lakes and the ocean. Billions of diatoms, each with a skeleton of silica, are found, for example, in the water of the Cottonwood river, Kansas. Diatoms are also very abundant in the ocean, together with animals that use silica in their skeletons, such as the sponges and rhizopods.

For some unexplained reason the waters contain and deposit, periodically, great quantities of silica in the limestones and sandstones. In this paper we will consider the deposits in certain limestones. There is an abundance of silicified honeycomb coral and chert in the Niagara limestone of the Wisconsin Silurian; the Onondaga limestone of the New York Devonian contains chert and silicified fossils in very great abundance; the Osage limestone of the Mississippian of Kansas and Missouri possesses quantities of chert packed in the zinc sulfid and lead sulfid togethed with silicified fossils; while the Wreford and Florence limestones of the Permian of eastern Kansas contain the chert and silicified fossils that are the subject of this paper.

The chert gravel of Lyon county, Kansas, has been studied in three situations:

I. These limestones have an average dip of twenty or twenty-five feet to the mile to the westward and are very resistant to erosive agencies, owing to the presence in them of great quantities of chert or impure flint. The Flint Hills, or Permian Mountains, as the early geologists named them, are being eroded more rapidly on their eastern face because the westerly dip exposes the underlying softer formations on this face to more rapid weathering. The chert debris is therefore distributed somewhat evenly for about fifty miles to the eastward of the present position of the Flint Hills.

II. At the present time west and east of Emporia we find more than a dozen hills and mounds of chert gravel resting on the Pennsylvanian shales and limestones, at an elevation of about 100 feet above the beds of the Cottonwood and Upper Neosho rivers and mostly between these streams.

A brief description of the Cottonwood valley to the sources of the streams which now drain it will help to understand the origin of these stratified deposits of water-worn chert so high above the present level of the rivers.

Beginning at Delavan, west of Council Grove and near the Flint Hills, we follow a semicircular ridge with an altitude of about 1,500 feet, past Lost Springs, Canton east of McPherson, Walton west of Peabody, to near Matfield Green into the Flint Hills again, and have the sources of five or six small streams that unite at Florence, altitude 1,270 feet, to form the Cottonwood river. At Strong City the bed of the river has an altitude of about 1,150 feet, the Wreford limestone, 1,340 feet, and the bed of the Cottonwood river about 1,100 feet at Emporia.

At McFarland, Kan., the core of a diamond drill prospect hole was interpreted by the Universtiy Geological Survey as to the formations penetrated belonging to the Pennsylvanian except the first 610 feet. This upper part of

the core showed 39 feet of soil and gravel and 571 feet of shale, holding two or three thin layers of "coal."

With all the upper strata of the Pennsylvanian shown at the east in the hills at Maplehill and in Buffalo Mound and the Cottonwood and Neva limestones on the west at Alma, this 610 feet of soil, gravel and shale resting on the Burlingame limestone, according to the interpretation, and bounded on the east and west by the limestones and shales of the Upper Pennsylvanian—the 571 feet of shale must be the filling of a 600-foot canyon on the eastern slopes of the Nemaha Mountains, before they sank from view and were buried. This canyon may, perhaps, have cut through the Nemaha Mountains from the vicinity of where Manhattan now stands.

When the Kansas Glacier pushed into the state some 500,000 years ago, it crossed the valley of the Kaw river and reached a zig-zag line a few miles south of Topeka and Lawrence. Before the advent of the Glacier the Kaw valley had been cut through the Flint Hills, where Manhattan now stands, by a river which drained all northwestern Kansas. The Kansas glacier thus forced the waters of the Big Blue, the Republican, the Solomon, the Saline and the Smoky Hill rivers to flow towards the Arkansas river across McPherson county. Part of this flood must have crossed the semicircular ridge, described above, and helped the Cottonwood river, then at a much higher level, to deepen and broaden its valley across the Flint Hills. The hills and mounds of chert gravel must represent the work of those ancient floods of a great Cottonwood river helped by a smaller Upper Neosho river. This gravel with a thickness of ten or more feet is stratified and faintly cross-laminated. In it I have found blocks of sandstone of a kind originating only west of Emporia. The silicified fossils in the gravel are the same in species as those in the chert of the Wreford limestone in the Flint Hills.

III. Under the bottom-lands of the Cottonwood and Neosho rivers near Emporia are six to eight feet of chert gravel like that in the hills nearby. This is also probably stratified, and was deposited at a much later period.

Seep water in this bottom-land gravel travels diagonally down to the river, three to five feet per day, and owners of wells that penetrate it say that it is an unfailing source of excellent water.

Iron carbonate in the chert weathers to a brown, and the length of time that the white chert has been exposed to the action of sun and rain is measured by the depth of the brown.

Chert and chert fossils are petrified limestone and calcium carbonate shells and corals. The calcium carbonate of the limestone and the shells is changed to the bicarbonate by carbonic acid in water and thus made soluble. Alkaline water containing silica in solution deposits the silica in place of the calcium carbonate, when it becomes a bicarbonate and soaks away. In a somewhat similar fashion wood is petrified. Petrified logs of Gymnosperms are frequently found in the Flint Hills.

Other rivers participated in the work of transporting chert gravel to the eastward of the Flint Hills. The Verdigris river, in southern Lyon county and northeastern Greenwood county, left low mounds of gravel along its margins. Fall river, in central Greenwood county, left a considerable gravel knoll where Eureka now stands.

When the Kansas glacier melted back to the northeast out of the state, much of the flood water was forced to the southward, carrying ice floes bearing gravel and bowlders of northern drift. Quantities of quartzite gravel were left near where Burlingame now stands. Much drift was floated as far south as Greenwood county. A small bowlder of coarse granite was found a few miles west of Eureka in the valley of Spring creek and a four-hundred-pound bowlder of fine-textured granite was found in the top of a high bluff bordering the Verdigris river in eastern Greenwood county. All the rivers of Lyon and Greenwood counties have evidently excavated their deep valleys since the Kansas gracier entered the state 500,000 years ago.

They are now engaged in filling them up, forming flood-plains. As the northern lands sank, possibly under the great weight of the Iowa and Wisconsin glaciers, the streams became less rapid and dropped their load of sediments outside their channels, at first rapidly and then more and more slowly as the sides of the channels became higher and higher. Now they can overflow their banks on an average about once in five years. The flood-plains of the rivers in eastern Kansas average about eighteen feet in depth.

Some years ago Alva Smith, a former member of this Academy, while supervising the construction of a sewage-disposal basin in the Neosho river flood-plain southeast of Council Grove, found the plain to be 25 feet deep. Down 12 feet he found the skeleton of a buffalo (Bison), down 20 feet he reached chert gravel and at the bottom, 4 or 5 feet of gravel. In the gravel he discovered several arrow points, one 30 or 40 feet from the channel. Near the basin was the stump of a tree that showed 175 annual rings, and yet the root bases were not covered. All this seems to prove that the flood-plains of the rivers in eastern Kansas have been built-up since the melting back of the Wisconsin glacier 25,000 years ago.

Kansas Weather and Its Effects on Crops

S. D. FLORA, Meteorologist, U. S. Weather Bureau, Topeka, Kan.

More erroneous statements have been circulated over the country about the weather and climate of Kansas than that of almost any other state. This tendency to exaggeration and to put our worst foot foremost probably dates back to the covered-wagon period.

The passage of the Kansas-Nebraska Act brought a flood of early settlers, fired with a religious fervor to make Kansas a free state, and the next rush occurred during the period of unrest immediately following the Civil War. A very large per cent of these emigrants were poorly equipped to contend with an unknown climate and unbroken prairies—conditions quite different from those to which they were accustomed. The result was much suffering and privation, and thousands of these settlers were forced to return to their original homes in the East. Naturally, they laid their failure to an unfavorable climate and bolstered up this idea by exaggerated accounts of what they had experienced.

Modern Kansans seems to have inherited this tendency to stress the unfavorable and striking features of Kansas weather and climate, while in most other states such things are either ignored or suppressed from outside circulation. As a result, such terms as "droughty Kansas" and "Kansas cyclone" have become almost an idiom in the spoken language of the country. This is by no means the only state that suffers from droughts, tornadoes, grasshoppers, cold waves, and blighting summer heat, but we seem to advertise them more. Reliable statistics tell of our great crops of wheat—the finest hard wheat in the world—of corn, alfalfa, and live stock that Kansas produces, but we seldom see anything in print about the bountiful rains and sunshine with which the state is favored in the growing season, about the exhilarating qualities of our climate, especially in the western counties, or about our wonderful brand of Indian summer weather in the autumn, which is equalled in few parts of the world. Also, the fact that our winters are milder, drier, and more nearly free from snowfall than those of states to the east and north is seldom mentioned or even realized.

Detailed weather records are now available for every part of Kansas. For 47 years state-wide weather observations have been made under the close supervision of the Weather Bureau and its predecessor in this work, the Signal Corps of the Army. In addition we have reliable records in large numbers that date back to the '70's and even the '60's. Our oldest record, at Leavenworth, was begun in 1836. For many years each county has been represented by at least one precipitation record while daily temperature readings have been recorded in approximately three-fourths of the counties.

At our first-order stations—Wichita, Topeka, Dodge City and Concordia—detailed records of local conditions have been made for more than 45 years, in most cases by self-registering instruments. In addition to temperature and precipitation, these give continuous records of wind movement, wind direction, sunshine, and state of the weather from hour to hour. Mention is made even of moonshine during night periods.

The accuracy of these records can scarcely be questioned. It is true the greater part of them have been made by coöperative observers, men and women who represent almost every vocation known in the state—farmers, doctors, school teachers, college professors, lawyers, undertakers, and housewives. These people have given their services without pay, actuated solely by motives of public duty and a devotion to science. Many such records have taken a lifetime to produce. For example: Mr. O. E. Skinner, at Columbus, Kan., has rounded out his 42d year as our observer, and there is scarcely a day missing in this long series of readings. At Ellinwood, Kan., the late Martin Musil kept a daily record of weather for 48 years and upon his approaching death bequeathed it as a sacred trust to his next in kin, who carried on until his death, which happened to be an untimely one. Then it went to the next in kin. Such records, when made with standard instruments and supervised by competent officials of the Bureau, are as trustworthy as it is humanly possible to produce. I have yet to find one of these coöperative observers who had devoted years to this work who would tolerate for a minute any inaccuracy or distortion of facts and figures in his records. He invariably has this in common with every earnest scientific investigator.

For 35 years these records have been compiled and printed month by month under the supervision of our office at Topeka and from time to time we have had printed summaries of all available records. The latest of these special summaries gives climate and weather statistics for Kansas from the beginning of the various records to the end of 1930 and we still have a considerable number of copies of these at our Topeka office for distribution to persons interested. During the past winter five persons employed in connection with the Civil Works Administration have been busily employed at our office making compilations and analyses of these data in much greater detail than we have heretofore been able to do with our limited force.

Many unsuspected and surprising facts about Kansas climate and weather have been established by this mass of data. Probably the most outstanding is that during the growing season Kansas is one of the most favored of all states when it comes to rainfall, and along with this we have more sunshiny days than most states—a combination that favors abundant crop growth. In the winter season, when crops are dormant, nature seems to hoard our precipitation and then, as if to make amends for being stingy, gives us from 71 to 78 per cent of the year's total fall in the six crop-growing months, April to September, inclusive. As a result, there are no other states in the country, except a few along the Gulf coast that, taken individually, receive as much rainfall during these six crop-growing months as the eastern third of Kansas. Even the middle third of our state receives approximately 20 inches in these six months, which is within 2 inches of the amount that falls in the same period over Illinois, Indiana, Ohio, New York, and the New England states. The western third of Kansas, once considered part of "The Great American Desert," has an average fall of 15 inches for this period, which almost equals the corresponding amounts in Michigan and Wisconsin and is approximately three-fourths the average for Iowa for these months.

Yet we know the western half of Kansas qualifies for a dry climate for two reasons. One is that this section has a high wind movement and an excessive amount of sunshine compared with other agricultural districts farther east,

and a high rate of evaporation results. Sunshine, which is an asset when there is abundant soil moisture, becomes a decided detriment, especially when accompanied by drying winds, when crops are struggling in dry soil. It also happens that the hottest months of the year in Kansas, July and August, are the most sunshiny. The other reason is the irregularity of rainfall in western Kansas. A number of years ago a tabulation was made for all parts of the country east of the Rockies of periods of 30 consecutive days during the crop-growing season when at least .25 inch of rain did not fall on any day. It was found that in the 20-year period from 9 to 12 such dry spells had occurred in Iowa, Missouri, Illinois, Indiana, and Ohio, while in Kansas the number showed a steady increase from 9 at the Missouri border to 33 in the far western counties.

Had nature not endowed western Kansas with a soil unusually retentive of moisture, and had not the immense amount of research been accomplished in adapting proper grain crops and developing proper methods of handling this soil, it is likely a great part of western Kansas would still be, as it was once considered, a part of "The Great American Desert," fit only for grazing live stock.

Normal temperatures over Kansas are almost ideal for corn. In July, the hottest month of the year and the critical month for this crop, normal afternoon temperatures range generally from 88° to 90° and night temperatures between 66° and 70°, except in the extreme western counties, which have cool nights, even in midsummer. Corn planting here, as in most other states, tends to start at about the time of the average date of the last killing frost in spring. While there is occasional damage to corn, as well as to potatoes, truck, and fruit from late spring frosts, the growing season is so long that fall frosts seldom do serious damage to staple crops, except occasionally the grain sorghums.

Kansas owes its prominence as a wheat state largely to the fact that this crop matures here before the heat of July and also to the absence of excessive soil moisture in winter, which helps minimize heaving. Also, our generous sunshine, even in winter months, is a help to wheat. On the other hand, the rapid decrease in our normal precipitation as fall approaches and a rather common prevalence of dry, windy weather in March and April do much to prevent the Kansas wheat crop from glutting the world's markets.

The most disagreeable feature of Kansas weather and the one that takes heaviest toll of crops is that normal summer temperatures and rainfall so often change to abnormal heat and drought with drying winds that sometimes develop into hot winds. The possibility of this must be taken into consideration in the successful planning of farm crops.

Excessively hot, dry summers stand out in memory and helped give the state a bad reputation in the '60's and again in 1874, the "grasshopper year." Recent hot summers of note are 1901, 1911, 1913, 1917, 1919, 1930, and, as it is scarcely necessary to mention, 1933. It is interesting to note that the drought of 1913 was in all probability the most damaging the state has ever experienced. Available records indicate that, with the possible exception of 1874, this was the driest summer ever experienced by white men in the state. It was attended by intense heat, as droughts usually are. At Clay Center the average maximum temperature for August that year was 107°, which is a mark never exceeded in the United States, except at a few of the hottest points in the

desert regions of the southwest. A record reading of 116° occurred at that place and at Hugoton, Kan., on June 25, 1913, which has since been equalled, but never exceeded in Kansas by readings of accurate thermometers properly exposed.

Winters in Kansas are inclined to be milder, drier, and more sunshiny than in other important grain producing states. However, we seem to be especially subject to the sweep of severe cold waves, accompanied by high winds. Blizzards, even in the western part of the state, are rare. That of March 26, 1931, was the worst since 1886. While we often have long periods of mild, pleasant winter weather, there is not a year on record without zero readings somewhere in the state and, as a rule, the low mark for the state will range from 10° to 20° below zero. The lowest on the state's record is 40° below zero, which occurred at Lebanon on February 13, 1905.

Another fact that has been definitely established is that average precipitation over Kansas does not show any progressive increase or decrease, in historic times, at least, nor is there any reason to think the wind movement is not as vigorous as it was in the early days when the cold was so keenly felt by the early settlers in their poorly constructed houses without adequate facilities for heating. However, recent investigations by Mr. J. B. Kincer, chief of the Division of Climate and Crop Weather of the Weather Bureau, indicate that for once the old settlers are right in claiming our winters are getting milder. For a period of 40 to 60 years there has been a noticeable tendency towards milder winters, not only in Kansas but over the entire eastern part of the United States. However, don't let this statement tempt you to part with your winter wraps or junk the heating systems of your homes. Bad flare-backs with intense cold have occurred in many parts of the country in recent years and are likely to occur in future winters. The reason for this moderation of winter weather is not known, nor do we know whether it will continue or perhaps a swing towards colder winters may come soon.

Correlation of weather, especially abnormal weather, and Kansas crops, offers an almost virgin field to investigators. Considerable progress has been made, especially by scientists of the State College and its branch experiment stations and by scientists of the U. S. Department of Agriculture, in correlating weather and wheat yields, but there are still new worlds to conquer in determining effects of weather and climate on many other crops, and on wheat for that matter.

Mr. J. B. Kincer, previously referred to in this paper, has recently found that each inch of rainfall in Kansas, from June to August, means 2.2 bushels of corn to the acre; at least this holds good for the past 20 years. Farmers of Kansas have grown, on the average, for the past 10 years, 5,500,000 acres of corn annually, which, multiplied by 2.2 gives a total of 12,000,000; so one good rain in Kansas during the corn growing season has made for the farmers of the state, at the average price of corn during the past 10 years, more than $8,000,000, and Kansas is only one of the 48 states in this agricultural country of ours.

Turning to other agricultural states, Mr. Kincer finds that in North Dakota one inch of rainfall from May to July, inclusive, produces about 6,000,000 bushels of oats; nearly 3,000,000 bushels of barley; nearly 1,000,000 bushels of potatoes; more than 500,000 bushels of flax seed, about 9,000,000 bushels of

wheat, and more than 125,000 tons of hay. Computed on the basis of average prices for the last 10 years, a good rain, one inch, in North Dakota, any time from May to July, is worth, on the average, the neat sum of $17,000,000 for these six crops alone.

Mr. J. Warren Smith, formerly chief of the Weather Bureau's Division of Agricultural Meteorology, found that when the July rainfall over Ohio had been less than three inches the yield of corn averaged 30.3 bushels to the acre, and when the rainfall had been 5 inches or more the yield averaged 38.1 bushels to the acre. This difference of 7.8 bushels an acre means a variation of 27,300,000 bushels of corn for Ohio, worth at the one time price of a dollar a bushel, over $27,000,000—a valuation of $13,500,000 per inch of rain at the right time over the state.

Smith also found that for the group of states comprising Ohio, Indiana, Illinois, Iowa, Nebraska, Kansas, Missouri, and Kentucky, whenever the rainfall for July has been one-half an inch or more above normal the yield of corn averaged 10 bushels to the acre more than when July rainfall has been one-half inch below normal. This average of 10 bushels to the acre means a definite increase in the corn crop over the eight states of something like 500,000,000 bushels, all depending on the difference of an inch in July rainfall. This, with good prices prevailing, represents a tremendous increase in the purchasing power of farmers in the central part of the United States, and a matter that can be anticipated with considerable confidence by the time July ends each year.

Digressing for a moment from the value of rain to crops, did you ever stop to consider the enormous amount of water that Mother Nature pours out in one rain? Kincer has computed that, in the case of Kansas, one inch of rain over the entire state means nearly 6,000,000,000 tons of water. Suppose you count tons of water at the rate of 150 a minute, 60 minutes an hour, 24 hours a day, and 365 days a year, without stopping day or night. At this rate how long would it take to count this six billion tons? Don't try, for you would be counting for the next 75 years.

Smith was materially aided in his research by a remarkable phenological record that had been kept 48 years at Waseon, Ohio, by Mr. Thomas Mikesell. Mr. Mikesell had recorded from year to year the life history of all crops in his vicinity, such as dates planted, dates coming above ground, dates of first cultivation, dates in bloom, dates of harvest, dates ready to use, per cent of crop good, and quality of crops. Along with this he had kept a record of weather conditions from day to day. His record enabled Smith to calculate the critical time on the development of corn, when rain or the absence of sufficient moisture had the greatest effect on it. This he proved conclusively was the 10-day period immediately following blossoming, which averages July 25 at Waseon.

In Kansas we have never been able to find a Thomas Mikesell with a record such as this that would enable us to determine definitely what time of the year corn reaches its critical stage. We have reason to think it occurs earlier than July 25 here and that it is more variable than in Ohio, but we lack the groundwork of phenological observations to prove it. Here is an untouched field of reasearch in Kansas that is worth the while of any person interested in crops, fruits, or foliage plants of any kind, and I commend it to

your servious consideration if you wish to leave a rich heritage to those who come after you.

Forecasting accurately weather conditions for a year, a season, or even a month in advance for Kansas would mean millions of dollars in the pockets of Kansas farmers and, incidentally, help all of us. For instance: if we knew right now whether next summer would be a dry one like the last or would produce the right kind of weather to make bumper crops, it would change the entire program of crop planting over the state this spring and it would go a long ways in determining how far, if any way, it would be necessary to go in order to prevent another price-demoralizing surplus next fall.

So far this problem of forecasting, even in a general way, the weather for a season in advance has baffled scientists, but we are far from admitting it cannot be solved. Here is another problem for you who wish to engage in research and have your name written high among the benefactors of mankind. I can assure you the Weather Bureau will be only too glad to make its wealth of records available to any earnest student along this line.

We have made a few discoveries along this line, some of them very significant and helpful. In Iowa Mr. C. D. Reed, section director of the Weather Bureau for that state, found that in 7 of the 10 cases when June averaged 3° or more above normal in that state July averaged above normal, and in 8 of 11 cases when June temperatures were 3° or more below normal July was colder than usual. He also found that a January 4° or more above normal in Iowa has been followed by a February warmer than usual 9 times out of 11 and that a cold January, with a mean temperature 6° or more below normal, has been followed by a cold February 6 times out of 7. He found that the greater the temperature abnormality in June the more certain the sequence in July.

Kansas records show even more strongly this connection between June and July abnormalities. In the 9 instances on our 47-year record when June averaged 3° or more above normal July temperatures have averaged above normal every time. That the hot summer last year was no exception to this I scarcely need point out to you. In 7 of the instances that June in Kansas has averaged 3° or more below normal the July following has averaged below normal 5 times. On our 47-year record only 4 Julys with temperature departures 3° above or below normal have followed Junes that did not have a similar though perhaps a lesser abnormality. Our relation between January and February abnormalities, however, is not as certain as in Iowa. The reason for this will make another interesting investigation.

In the 10 instances out of 14 on our 47-year record, when the average rainfall in June was an inch or more in excess of normal, the July following has also been wet. In the 11 instances out of 15 when our rainfall for June was an inch or more deficient the rainfall for July was also deficient.

Records show that 9 times out of 16 a deficiency of any amount in July rainfall in Kansas has been followed by a corn crop below the average, and 6 times out of 7 a wet July has been followed by a corn crop above the average. These statements apply to the state as a whole. They could probably be worked out more definitely by splitting the state into sections. If you are interested, here is your chance to try your hand at something worth while. The figures of rainfall and crop yields are readily obtainable.

The significance of this relation between July rainfall and corn yields begins to appear when we consider that a marked abnormality in temperatures in June is more than likely to continue through July and that July weather determines the corn crop. It is possible, using this line of investigation, to state with considerable degree of assurance by the end of June whether the Kansas corn crop will be above or below the average, though we know that hot, dry weather in June seldom, of itself, hurts corn materially.

Just as a concrete and somewhat unexpected example of the use to which a correlation of weather abnormalities can be put: At the Iowa State Fair, held the latter part of August, last summer, the Iowa Department of Agriculture distributed a bulletin prepared by Reed, stating, in effect, that the probability of the Iowa corn crop being injured by frost before it matured that fall was less than 5 per cent. This, as explained in the bulletin, was based on Reed's investigation, which shows when the June temperature over Iowa has been 2° or more above normal 95 per cent or more of the corn crop has escaped frost damage 12 times out of 12, or 100 per cent of the time. June last year in Iowa averaged 8.3° above normal. Results proved the soundness of the line of reasoning as considerably less than 5 per cent of Iowa corn was frost damaged last fall.

In Kansas we do not have as much fear of frost damage to corn in the fall as they have in Iowa, but we do have many crops, including corn, that are jeopardized by frost danger in the spring. Perhaps sufficient investigation would make possible advance information here. This is another virgin field of research work that is wide open to any one.

In wheat Kansas is the premier state, and our scientistis of the Agricultural College and its experiment stations have compiled a fund of information touching on the effects of weather on the wheat crop. These have been given wide publicity through bulletins of the College and county agricultural agents and have helped us raise two kernels of wheat where but one grew before.

It was a surprise to me and will probably be to you to know that Russia was the pioneer country in investigating the effects of weather and climate on crops yields. Russia began this work in 1896 and by 1912 had 81 experiment stations where meteorological records were being kept as near as possible to test plots.

Similar records were begun in Canada in 1915 at 14 experiment farms, with particular attention paid to spring wheat.

Very little was done along this line in our own country until 1916 and then the war emergency prevented material progress for several years.

Now that the emergency of overproduction and underconsumption has caught us in a welter of opinions about how much and what kinds of crops to grow we find we have very little knowledge about how much ground to seed in order to produce a fixed amount of food stuffs. With a normal year a definite reduction of acreage will produce definite results. If the season turns out unusually favorable we might again find ourselves with an unsalable surplus, and should another great drought hit the Middle West, the bread basket of the Nation, we might conceivably, in the opinion of some men, face a deficiency in our food supply. Science finds itself unable to give definite answers to the problems that come up in this connection. So many new worlds yet remain to be conquered in investigating these questions.

Putting together this jig-saw puzzle of weather sequences, especially abnormal weather, and correlating them with crop production, even in Kansas, is as much a challenge to research workers as the unexplored polar regions have been to men like Peary, Scott, Amundsen, and Byrd. They seem promising of results that may, perhaps, add millions to the wealth of the state and to the happiness of its people.

With the return of a more active demand and higher prices for farm products I feel sure some one, possibly from the group that meets in Wichita this week, will accept the challenge.

Cacao and Elimination: Some Personal Experiences

ARTHUR W. BARTON, Fort Hays Kansas State College, Hays, Kan.

There are not many references in the scientific literature to the effect of cocoa and chocolate upon the human organism, other than that it predisposes one to attacks of catarrh, and in some instances to colitis.

The following statement is based upon three experiences the writer had during the years of 1933 and 1934: In the first instance about 750 grams of well-known brands of milk chocolate were ingested in "doses" of 50 to 60 grams per day in the latter part of August. In the second instance about 1,000 grams were consumed during 20 days in December and January. While in the third case, 1,500 grams were eaten during March and April, 1934. In each instance the general symptoms were the same, viz., nasal catarrh, indigestion, and constipation, in the order listed. Each succeeding experience was a little more severe, longer continued, and recovery slower—full recovery has not yet taken place (May 10) from the last attack.

The indigestion was characterized by the formation of great quantities of gas in the stomach and intestines. At the time of greatest distress no relief was experienced by taking such antiacids as calcium carbonate, magnesium carbonate and oxide, and sodium bicarbonate. The ingestion of carbohydrates aggravated the condition. The constipation manifested itself at times as spastic colitis—so diagnosed by a physician. During the worst of the symptoms the abdominal region was exceedingly sore and painful.

These "experiences" were not endured as scientific experiments; but somewhat from a lack of the full appreciation of the real cause, in the first two attacks, perhaps mostly from the love of chocolate. But at this time there is a deep-rooted conviction that the immoderate consumption of chocolate is injurious to those of a catarrhal diathesis, because of its decided action on the mucous membrane.

Longevity in McPherson County*

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There being no official registrations of births and deaths and desiring to know the facts of longevity in my own city and county, with the assistance of my class in personal and community health, during the spring of 1923, I tabulated all the marked graves in the McPherson cemetery, about 2,000, copying the dates of birth and death. The following year we tabulated the graves of all cemeteries in the county, about 2,000 more graves.

We divided this material into six groups; group one, those who had died before 1880. Group two, 1880-'90 and so on to 1920. We then calculated the average age for each period. The per cent of deaths: *a.* under 21 years; *b.* under 5 years and *c.* under 1 year. The results are tabulated separately for the city and rest of county cemeteries. The reader may draw his own conclusions.

TABLE 1.—Lonevity in McPherson county.

	1920	1910-1920	1900-'10	1890-1900	1880-'90	Before 1880
Average age, McPherson city cemetery	......	54	50	42	29	24
Average age, county	53.5	53	42	34.5	24.5	23
Per cent deaths under 21 years, city	......	13	17	37	51	56
Per cent deaths under 21 years, county	13	17.5	30	32	55	52.5
Per cent deaths under 5 years, city	......	7	11	24	33	36
Per cent deaths under 5 years, county	7.8	11.3	18	22	42	38.6
Per cent deaths under 1 year	5	7.3	12.6	16.1	24.5	33.3

* Condensed from a paper, "Longevity in McPherson County," presented at the Winfield meeting April, 1926, and from the presidential address, "Longevity and Some Other Matter," at the Lawrence meeting, April, 1927.

Measurement of High Resistance with a Relaxation Oscillator

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Relaxation oscillators are in quite common use to-day for generating audible frequency oscillations up to 10 KC per second (*1*). They are generally in the form of a multivibrator (*2*) glow discharge tube, or grid leak oscillator.

By a relaxation oscillator is meant a generator of distorted currents whose variations are due to the charging and discharging of a condenser through a resistance.

Two years ago it occurred to the writer that the operation could be inverted and the high resistance grid leak be measured by counting relaxation oscillations of long periods. Hund (*1*) mentions this possibility, but his technique is essentially the same as the standard ballistic galvanometer method except for the fact that he substitutes a plate current ammeter for the ballistic galvanometer.

The operation of measuring high resistances to be presented here, involves a minimum of apparatus at low cost and has offered more consistent results with the average student than the standard loss-of-charge method.

The circuit used is a simple shunt-fed Hartley oscillator, in which the plate and the grid coils consist of the primary and the secondary, respectively, of an audio frequency transformer. One-microfarad condensers are used for a stopping condenser and for a by-pass condenser across the 45-volt plate battery. The only capacitance in the oscillatory circuit is the distributive capacitance of the grid coil. Two grid condensers, of one mfd. and .01 mfd., have been used with grid leaks up to 50 megohms for controlling the relaxation oscillations. The grid leak is in series with the grid, and the grid condenser is shunted around it. The tube used is a 201A with normal filament current and with a 45-volt potential on the plate. A pair of Baldwin phones in the plate circuit render the oscillations audible.

Altho no especial precautions were used to keep the circuit stable, the oscillations showed good stability. A resistance in series with the stopping condenser might improve the circuit. The apparatus was mounted on a hard rubber panel, and two stand-off insulators were used to hold the resistors tested.

So far, measurements have been made using resistors from .1 to 50 megohms with 1 mfd. and .01 mfd. condensers shunted around them. The clicks produced in the phones, representing the intervals between the successive groups of oscillations, are readily counted by the observer, since they range from 2 to 3 oscillations per second to one per 70 seconds.

The oscillator was calibrated by using 14 units, singly, and in combinations as grid leaks. An average of 40 oscillations were counted and the time recorded with a stop watch. The periods varied from .422 seconds to 70.1 seconds when using resistors between .1 megohm and 50 megohms with the 1 mfd. condenser; while the same resistors with a .01 mfd. condenser produced periods from .183 to .902 seconds. (Ten megohms was the smallest resistance used with this last condenser.)

The resistors, as supplied by a radio company, were measured with a Wheatstone bridge and also by a direct-deflection method. A 100,000 ohm Siemens-Halske manganin resistor was used as the comparator. The two methods agreed to within ⅛ to 1 per cent.

The calibration curve representing the period as a function of the resistance consists of 50 points lying on a very smooth curve. The relationship is practically linear up to 10 megohms when using the 1 mfd. condenser. When using the .01 mfd. condenser, the curve is practically linear between 10 and 50 megohms.

The procedure in measuring a resistor consists in determining the period of the clicks when the resistor is used as the grid leak. The calibration curve is then consulted and the resistance determined. The calibration curve gives results of 1 per cent or less, with the present circuit.

Comparison of resistances can also be made quickly with the above circuit by merely listening to the frequency of the phone clicks. Some measurements on the hands have been made this way. The clicks may also be counted by a relay in the plate circuit operating a mechanical counter.

The limit of resistance that can be measured is determined by the leakage of the various parts of the circuit which are at present mounted as described above. One rectangular piece of this material produces relaxation oscillations of 6 minutes, which would give an upper limit to the circuit of 200 to 300 megohms.

It is interesting to note what fraction of the condenser must be discharged before oscillations can be resumed. (This is what causes the clicks.) Since $(1-e^{-t/RC})$ is the percentage of charge that must leak from the condenser, several computations were made. Thus, when using .2 megohm and 1 mfd. condenser we find that 84.5 per cent of the charge leaks off. This is practically constant for all leaks up to 10 megohms. At 50 megohms only 75.1 per cent of charge had to leak off. When using 10 to 50 megohms with the .01 mfd. condenser 83.1 per cent of the charge leaked off. On this portion of the curve one could calculate the resistance from the expression $\frac{t}{RC} = \text{constant}$.

LITERATURE CITED

1. August Hund: "High Frequency Measurements." McGraw-Hill. 1933.
2. Abraham and E. Bloch: "Comptus Rendus," 168, 1105. 1919.

The Near Ultra Violet Spectrum of Copper Produced by the Hot Spark in Vacuo.*

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(PLATE II)

As early as 1897, when interested in the production of the newly discovered X-rays, R. W. Wood (*1*) made reference to the hot spark. Since then many experimenters have used it as a device for producing higher degrees of excitation.

In 1918 R. A. Millikan and R. A. Sawyer (*2*), while working with spark potentials generated by the use of condensers and a static machine, observed that it is possible to obtain hot metallic sparks in vacuo where the gases play no part in the discharge. It occurred to them that by building a vacuum spectrograph, the knowledge of any particular spectrum might be extended into the extreme ultra violet. Having removed the difficulties imposed by the absorbing properties of the air, it was found that the radiating properties of the source were enhanced to the extent that they were only limited in the extreme ultra violet by the properties of the grating itself.

Later, in extending the photographed region, Millikan (*3*) used an intermittent spark between electrodes 1 mm. apart in connection with Leyden jars charged to several thousand volts by an induction coil. However, he had difficulty with this type of spark due to residual gases in the metal. Thus it became necessary to run a diffusion pump continuously and spark at fairly long intervals. It was also found advisable to insert an outside spark gap in series with the vacuum gap.

Edna Carter (*4*), at the Mt. Wilson Observatory, used the hot spark as a source to photograph Ca, Mg, Cd, Ti, and Fe. Her spark chamber consisted of a glass bulb 12 cm. in diameter. Since some of the foregoing metals vaporize fairly easily, the electrodes had to be spaced from 3 to 4 mm. Here, as in previously cited references, the periods of exposure aggregated eight hours of operation. During that time she experienced trouble with the spark breaking over into a gaseous discharge. Very little difference was noticeable between her Ca and Mg sparks in vacuum and those in air. Titanium, however, showed the presence of enhanced lines; and, as before, the arc spectrum of Fe resembled rather closely that of the vacuum spark.

J. A. Carroll (*5*), of the University of Cambridge, was introduced to the vacuum spark by Millikan. His work consisted of the excitation of the heavier elements and series classification in the spectra of ionized atoms homologous with copper, silver and gold. A condenser of less than 1 microfarad was charged to 20,000 volts by a 2-kw transformer and discharged across a spark gap in vacuo. He observed HgII, CaIII, InIII, TlIII, GeIV, SnIV and PbIV.

In the work done by the writer, the object was to photograph copper in the hot spark with the hope of procuring some new CuII lines, and possibly CuIII, in the air region, and to supplement the observations in the vacuum region being made by other workers in this laboratory.

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* Master's Thesis. M. I. T. (1934).

PLATE II

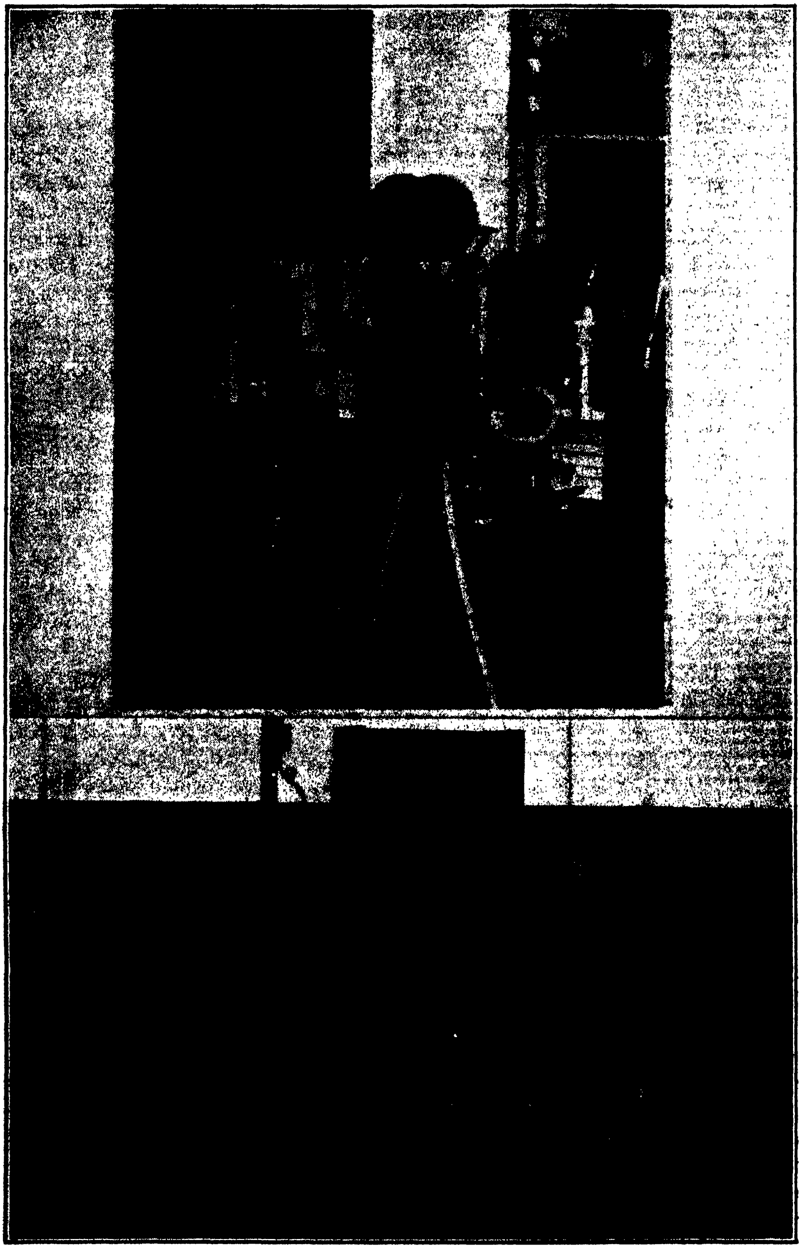

FIG. 3. (*Upper*). Spark chamber and portion of vacuum system mounted for operation.
FIG. 2. Portion of room comprising the camera with mounted grating in background.

APPARATUS AND PROCEDURE

When the problem was first undertaken by the writer, the apparatus had already been constructed by Doctor Harrison and Mr. Evans (*6*) of the Institute. They were ready to photograph the spectrum of copper in the hot spark on the 15,000-line, 21-foot grating.

The spark took place between two copper electrodes spectroscopically pure and under a pressure of 10^{-4} mm. of mercury: At that time the older type of spark chamber designed by Doctor Harrison was used. However, some of the earlier experimenters with the hot spark used a spark chamber constructed of glass. In our apparatus, the glass was replaced by a brass chamber which was more durably constructed and possessed greater facility for handling. It had been so designed that water could circulate in the arms of the electrodes and also in the region of the main spark chamber. By means of this construction, one was able to run the spark continuously without any serious damage to the apparatus. The greatest difficulty occurred at the arm joints, which were sealed with a wax called "ackumpucky." This trouble arose when the joints became warm so that the wax softening allowed the pressure to rise.

The spark chamber was connected by a flexible tubing of 1½ inches inside diameter to a large stopcock. The latter was made of brass and was held rigidly in an iron frame. The connection was made by bringing two flanges 4 inches in diameter together with ackumpucky inserted in the groove. The flanges were held together with clamps.

This type of joint was found to be very efficient and convenient since the vacuum system could be easily and swiftly disconnected at such a flange. On the low-pressure side of the main stopcock, a pyrex to metal joint was made with the aid of sealing wax. The pyrex tubing, 1 inch in diameter, led to a mercury trap. Here a large-size Dewar flask was packed with dry ice (CO_2 snow), using acetone to make a better contact with the walls of the mercury trap. The Dewar flask was 18 inches in length and 5 inches in diameter. It was found unnecessary to use liquid air to condense the mercury vapor that came over from the diffusion pump.

The low-pressure side of the mercury trap was connected to a large metal mercury diffusion pump. It, in turn, was in series with a Cenco-Hyvac oil pump. There was another metal to pyrex joint on the high-pressure side of the mercury diffusion pump. This time, picein and stopcock grease were used, the picein mainly to keep the stopcock grease from entering the diffusion pump.

The electrical circuit (*6*) was quite similar in design to that used by previous experimenters with the hot spark. The supply consisted of 220 volts a.c. on the primary of the transformer. In the primary circuit, a "dead-man" switch was fashioned so that protection could be obtained from the high potential charges on the condensers. The secondary side of the transformer yielded 100,000 volts, which was rectified mechanically using, for this purpose, a synchronous induction motor. A resistance, ammeter, voltmeter and interrupter were inserted in the primary circuit. The speed of the interrupter could be varied by changing its ratio wheels. The condensers were built of tinfoil waxed to a good grade of glass, each unit consisting of fifteen plates. The plates were separated by one-half inch air space, and the capacity of a single unit could be changed by drawing out the "spreaders" connected in

common to a bar of copper. A change in capacity became necessary whenever the motor of the mechanical rectifier broke down and the supply to the spark gap was changed to a.c. Two condenser units, placed in series-parallel, provided a capacity of .028 microfarads. The vacuum spark was connected across the two condensers and in series with an outside gap.

It was observed throughout the experiment that, in general, the alternating spark was less steady in performance than the direct-current spark. The major difficulty with the a.c. spark was in puncturing condenser plates during an exposure, more plates being broken in the short time during which a.c. was used than during the entire experiment with d.c. Moreover, as with previous experimenters, there was trouble due to sputtering of the electrode metal on the quartz window of the spark chamber. Light coming through the quartz window would take on a greenish appearance characteristic of copper. The sputtered window had to be removed, cleaned with nitric acid, dried and replaced, the exposure being interrupted during this interval. The front window of the chamber had been previously cleaned with rouge which was much slower than using nitric acid. The entire operation of cleaning the window and recovering the necessary vacuum was performed in the minimum time of thirty minutes. It might also be said that glyptal and ackumpucky were absolute necessities at such moments.

In obtaining the results incorporated into this report, the apparatus was set up for a final time before the 21-foot, 15,000-line, normal incidence grating. The slit width was .03 mm. and an intermittent exposure was taken for nine hours. Plates were placed so that the entire first order and second order, up to 5,000 Ångstroms, were taken in three exposures. The lines in the second order were not as strong as those of the first. Therefore, it is quite possible that many of the fainter lines did not appear in the second order. Figure 1 shows the spark chamber and a portion of the vacuum system mounted for operation, while figure 2 shows the grating and a portion of the room comprising the camera.

METHOD OF MEASUREMENTS AND CALCULATIONS

In the wave-length measurements, a Pfund (7) iron arc was found to be most suitable for the production of a comparison spectrum in the region λ-2200 to λ-5000. For trial measurements of the plates, the writer made three settings on each line with the hope of obtaining a high degree of accuracy. Very fortunately, Doctor Burns of the Allegheny Observatory and Doctor Meggers of the Bureau of Standards being in attendance at the Spectroscopy Congress at M. I. T., July, 1933, gave the writer some timely suggestions as to their own methods of measuring plates. These suggestions were followed as closely as possible in the following manner.

The plate was measured in one direction with one setting of the comparator on each line, the plate having been previously arranged so that the comparator readings increased with wave length. This simplified later wave-length calculations considerably. After the first run, the plate was changed end for end and measured again in the same direction, having racked the carriage to approximately the initial position of the first reading. The end line was so adjusted that the number after the decimal point for the first reading plus that of the second reading totaled 1,000. The number before the decimal

point was not needed for the second reading. In this manner, a quick and very efficient method of averaging two readings was obtained.

Some of the best lines with regard to sharpness and pole effects were chosen from both ends of the plate. In choosing such lines, they were marked either "a" or "b" under the pressure by Meggers and Burns. The letter "a" means a line which has a slight shift toward the ultra violet due to pole effect, while "b" signifies a slight shift toward the red. With the linear dispersion of the end lines completed, the wave length of the measured lines was computed. Their wave length differed from the accepted values by a $\Delta \lambda$. This difference was plotted against the comparator setting giving the desired deviation curve. From this curve a correction was madde for the wave length computed by the linear dispersion.

As shown in the table of wave lengths which immediately follows, the measured wave lengths range from 5428.014 Å to 2175.012 Å, the region of absorption by the air as indicated by the decreasing intensity of the lines. The upper wave-length limit is due to the decrease in sensitivity of the plates (Eastman #40), these results providing a qualitative range for which the above plates are sensitive. Further investigation for shorter wave lengths in the copper spectrum requires the use of vacuum methods which are being applied by other investigators in this laboratory. The intensities associated with the tabulated results have been judged visually by the author and are entirely relative.

Tabulated Results.

Wavelengths measured in the hot spark spectrum of copper:

Intensity	Wavelength	Intensity	Wavelength	Intensity	Wavelength	Intensity	Wavelength
1	2175.012	1	2446.905	5	2522.392	0	3198.622
10	2179.406	1	2447.668	3	2523.139	3	3208.216
1	2195.742	3	2453.102	3	2524.970	1	3212.358
2	2215.186	5	2458.798	3	2532.043	2	3213.087
2	2226.842	1	2459.502	3	2532.900	5	3220.392
1	2229.922	3	2462.143	3	2533.697	2	3230.235
0	2230.992	2	2465.939	10	2535.318	1	3234.581
1	2249.033	10 nv	2468.521	1	2618.340	2	3235.649
2	2263.863	1	2475.180	5	2666.299	2	3236.312
2	2286.673	2	2478.344	30	2689.305	5	3238.262
1	2336.271	20	2482.410	30	2700.969	1	3238.888
3	2346.254	20	2486.510	25	2703.189	5	3242.023
1	2355.106	3	2496.121	5	2975.528	20	3243.238
3	2368.256	2	2497.676	5	2978.874	125	3247.525
3	2376.409	3	2504.702	3	2997.365	15	3251.905
2	2391.835	1	2505.664	5	3010.779	3	3256.506
5	2405.598	2	2507.453	10	3036.115	3	3258.832
3	2412.457	3	2508.069	10	3063.436	2	3260.621
1	2421.932	10 nv	2508.533	2	3073.819	2	3261.422
5 nv	2428.426	3	2511.348	5	3094.004	2	3263.605
2	2430.497	3	2516.356	1	3108.543	3	3264.882
5	2435.967	3	2516.858	3	3126.097	2	3268.164
1	2440.224	3	2518.361	1	3133.948	2	3268.904
1	2442.769	3	2518.829	5	3162.706	20	3269.614
30	2444.537	3	2521.021	10	3194.112	125	3273.960

Intensity	Wavelength	Intensity	Wavelength	Intensity	Wavelength	Intensity	Wavelength
20	3278.365	2	3359.847	2	3595.692	25	3719.887
20	3279.822	3	3361.861	2	3599.094	3	3720.998
2	3280.705	3	3365.357	3	3600.815	20	3726.117
3	3282.734	3	3370.440	3	3601.978	3	3735.221
2	3284.400	2	3372.873	3	3611.035	5	3736.416
10 nv	3290.526	2	3381.388	2	3625.586	5	3737.185
2	3291.421	2	3382.954	5	3636.019	3	3737.805
2	3292.875	1	3386.107	3	3638.008	5	3742.190
2	3293.579	5	3389.305	5	3639.411	20	3744.699
2	3294.470	3	3390.293	2	3646.672	20	3748.259
3	3295.061	3	3409.079	3	3652.880	25	3752.058
3	3296.397	3	3409.832	2	3657.681	3	3753.159
5 nv	3298.507	10	3426.684	3	3660.329	5	3754.501
2	3300.870	5	3428.756	5	3661.441	3	3759.431
2	3301.391	1	3436.027	3	3669.183	4	3760.167
3	3302.324	5	3438.140	3	3673.499	4	3762.134
20	3307.945	5	3442.758	3	3681.653	5	3763.982
3	3316.373	2	3444.453	25	3686.534	3	3768.746
5	3317.206	2	3445.640	5	3694.675	5	3771.490
3	3319.673	3	3450.331	5	3697.538	3	3773.083
3	3321.548	2	3568.857	3	3699.179	20	3774.870
3	3330.282	2	3577.060	3	3701.800	20	3778.384
10	3337.845	3	3578.521	10	3702.930	5 nv	3780.071
2	3339.694	2	3580.834	3	3703.896	5	3781.588
3	3341.760	3	3586.760	2	3706.762	10	3784.018
2	3343.240	5	3591.477	5	3710.466	3	3784.648
2	3344.963	2	3593.504	3	3713.397	3	3788.011
3	3358.755	3	3594.809	10	3715.038	30	3790.808

Intensity	Wavelength	Intensity	Wavelength	Intensity	Wavelength	Intensity	Wavelength
2	3792.489	5	3881.701	5	3961.961	20	4043.458
3	3794.323	5	3884.590	2	3967.983	15	4045.926
5	3798.984	3	3885.974	5	3968.736	2	4049.985
5	3801.042	3	3887.734	3	3977.600	2	4053.158
2	3801.928	2	3890.626	10 nv	3980.909	2	4061.760
20	3804.132	5	3893.631	10	3982.492	5	4062.641
15 nv	3807.441	2	3897.659	15 nv	3991.669	2	4064.172
20	3809.193	3	3898.617	10	3995.299	15	4066.006
3	3811.637	20	3899.491	10	3996.987	3	4067.053
2	3812.331	2	3902.300	10	3999.743	15 nv	4072.302
20 nv	3813.549	5	3903.207	5	4000.945	20	4077.766
3	3822.909	2	3905.050	5	4001.370	10	4082.295
3	3825.289	3	3910.673	2	4003.542	10	4084.982
15	3826.078	5 nv	3911.889	20	4005.011	3	4090.468
5	3831.531	15	3913.507	10	4008.906	2	4096.213
20	3834.200	10	3919.112	10	4011.917	2	4098.226
15	3838.540	3	3928.195	10	4012.718	2	4106.219
3	3845.437	5	3929.570	10	4022.671	10	4111.432
3	3846.163	10 nv	3933.595	3	4025.048	5	4121.091
2	3858.326	5	3942.515	10	4026.395	15	4123.334
2	3863.785	5	3947.336	10	4027.658	3	4128.257
3	3865.181	3	3949.579	5	4029.643	2	4137.535
3	3866.297	3	3951.067	15	4033.050	3	4141.448
3	3873.210	5	3953.845	2	4035.359	5	4143.595
3	3873.960	5	3955.215	15	4038.523	3	4144.944
5	3874.947	5	3956.647	15	4039.447	2	4147.172
5	3877.205	2	3959.394	5	4044.233	15	4150.539
3	3878.339	5	3959.849	2	4042.026	3	4162.101

Intensity	Wavelength	Intensity	Wavelength	Intensity	Wavelength	Intensity	Wavelength
3	4165.292	10	4360.129	3	4399.701	50	4555.895
15	4177.911	2	4361.681	3	4408.238	2	4571.327
5	4283.398	3	4363.017	3	4409.625	3	4573.226
3	4272.467	1	4364.282	2	4414.908	1	4581.915
2	4286.564	3	4365.997	1	4416.887	5	4586.990
2	4288.332	2	4367.133	10	4420.349	40	4588.674
5	4313.380	2	4368.068	1	4430.133	2	4590.883
0	4314.700	3	4369.245	2	4435.607	1	4591.610
2	4316.831	3	4370.109	15	4436.219	1	4596.037
4	4318.430	2	4370.759	2	4439.195	3	4596.880
2	4323.603	2	4371.242	10	4445.479	2	4597.894
1	4325.041	1	4372.733	1	4449.247	1	4598.806
1	4328.491	3	4373.313	2	4453.584	2	4608.406
4	4334.800	2	4374.309	20	4457.664	2	4610.743
2	4335.613	5	4375.336	10	4480.340	1	4611.594
3	4337.302	5	4377.017	1	4482.210	2	4617.491
3	4339.510	3	4377.969	20	4485.198	3	4623.715
3	4341.937	3	4379.188	2	4488.183	3	4628.436
7	4344.310	5	4382.125	2	4490.961	2	4629.419
2	4344.940	15	4384.442	25	4493.948	2	4631.535
1	4345.945	2	4385.280	3	4496.992	2	4634.214
3	4346.683	10	4386.219	1	4497.823	3	4635.812
5	4348.994	5	4388.149	3	4499.450	3	4636.847
20	4351.885	2	4388.964	40	4506.004	5	4638.869
20	4352.694	1	4390.280	40	4509.368	5	4641.697
25	4355.330	1	4391.305	5	4527.563	3	4644.899
10	4355.972	3	4392.371	25	4530.790	5	4649.131
15	4356.697	3	4395.183	5	4540.233	125	4651.086
2	4358.725	5	4396.292	30	4552.491	2	4657.319

Intensity	Wavelength	Intensity	Wavelength	Intensity	Wavelength	Intensity	Wavelength
5	4661.358	3	4805.618	5	4912.387	2	5036.645
10	4662.566	100	4806.610	5	4912.977	2	5037.547
3	4667.277	5	4807.011	30	4918.417	2	5044.691
30	4671.683	25	4810.945	3	4926.448	0	5047.280
15	4673.552	100	4812.976	5	4927.353	5	5051.788
25	4681.988	5	4824.126	30	4931.745	2	5053.152
10	4692.264	10	4824.592	10	4937.237	10	5058.597
2	4697.353	2	4829.541	2	4944.929	3	5065.492
60	4704.567	10	4831.209	2	4946.667	2	5067.099
5	4710.010	1	4841.272	10	4953.766	2	5070.665
15	4713.219	3	4843.635	5	4964.688	2	5077.285
5	4724.298	20	4848.795	5	4971.567	40	5089.605
10	4736.244	25	4851.235	3	4972.885	2	5092.966
5	4736.581	40	4854.937	10	4979.257	2	5094.146
125	4739.708	10	4860.654	3	4984.245	30	5105.606
10	4741.347	10	4861.258	5	4985.502	1	5106.221
10	4742.904	2	4824.633	2	4992.123	1	5146.624
20	4752.279	1	4848.832	1	4995.188	15	5153.209
25	4758.383	1	4851.290	2	5006.794	5	5197.614
3	4766.670	2	4854.986	40	5012.532	20	5200.557
10	4781.227	1	4883.252	5	5016.949	10	5218.188
10	4783.385	5	4888.877	2	5021.239	10	5218.339
3	4797.768	3	4901.482	2	5022.548	5	5287.780
75	4800.139	1	4906.882	1	5032.615	3	5320.207
3	4803.390	30	4909.795	1	5034.668	3	5374.946
						30	5428.014

The writer wishes to express deep gratitude to Dr. George R. Harrison, Director of the Research Laboratory of Experimental Physics, for the privilege of using the grating and for his many helpful suggestions throughout the problem. Appreciation is also shown for the timely suggestions received from Dr. Kervin Burns of the Allegheny Observatory and Dr. W. F. Meggers of the Bureau of Standards while measuring the plates.

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An Economical Method of Scoring Tests with Differentially Weighted Items

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The chief obstacle to a more extensive use of tests with differentially weighted items is the high cost of scoring such tests. The method here described is an adaptation of our Perfo-Score procedure previously described in the transactions of this academy (*1*). This procedure reduces the cost of testing through (1) saving the question booklets for repeated use in testing by having answers recorded on separate answer sheets; (2) marking as many as 25,000 answers per minute with perfect accuracy; and (3) facilitating the counting of scores by confining the examinee's answer records to an orderly arrangement on a single compact sheet instead of scattering them irregularly throughout a lengthy question booklet.

To utilize the Perfo-Score procedure tests having differentially weighted items require not only separate answer sheets but also a separate specially adapted scoring sheet for each key. Thus, for example, the Strong Vocational Interests Tests would require an answer sheet and one scoring sheet for each vocation in which the examinee desired to know his rating. All of these sheets would be stacked on an alignment board in Perfo-Score fashion with the answer sheet, properly marked by the examinee to indicate his choice of response to each question, placed on top of the stack. An awl would then be thrust through the entire stack of sheets at each marked answer location to record the examinee's choices on all of the scoring sheets.

If then the appropriate numerical value of each answer location is printed at the proper point on each scoring sheet, the score on any key can be found by adding algebraically all items which are marked by perforations. The adding of scores can be simplified by providing separate scoring sheets for positive and negative values or by printing positive values on one side of the sheet and negative values on the other.

To obtain still greater speed and accuracy of scoring and to obviate the need of an adding machine each of the numerical values of any key may be represented by a simple closed geometrical figure through whose center the perforations will show plainly. Ten such contrasting geometrical figures will suffice if different colors are utilized to represent successive cycles of tens. Thus 1 may be represented by a black square, 11 by a red square, 21 by a green square, etc.; 2 may be represented by a black circle, 12 by a red circle, 22 by a green circle, etc. Here again the negative values may appear on one side of the scoring sheet and the positive values on the other.

Calculating the score will then consist of counting the number of perforated figures of each value, multiplying the number of figures of each form by their value, adding these products and subtracting the negative from the positive values. This simple procedure can easily be carried out and checked by the individual high-school or college student.

The modified Perfo-Score procedure here presented thus reduces the cost

of scoring tests with differentially weighted items to that of one scoring sheet for each key and leaves the question booklet unimpaired for continued use in testing.[2]

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2. Patent pending.

A Check List of the Amphibians and Reptiles of Ellis County, Kansas

L. A. BRENNAN, St. Joseph's College, Hays, Kan.

During the years 1931-1934 the writer has made a study of the amphibian and reptilian fauna of Ellis county, Kansas. The specimens collected have been placed in the Department of Zoölogy of the Fort Hays Kansas State College, Hays, Kan.

Ellis county is only a short distance west and north of the center of Kansas. The surface of the county is of the same character as that of most of western Kansas, one vast stretch of prairie, almost destitute of trees, except for a few here and there surrounding farm houses and a narrow strip along the principal streams.

The principal streams are the Saline river on the northern boundary, the Smoky Hill river on the southern boundary and Big creek, midway between the northern and southern boundaries.

The writer is indebted to L. D. Wooster, Department of Zoölogy, Fort Hays Kansas State College, for the use of his unpublished records and also to Leo Brown, a graduate student at the State College in Hays.

The following list is a record of the species taken:

SALAMANDER

Ambystoma tigrinum (Green). Tiger salamander. Twenty larvæ and two adults were taken in a pasture pond on the A. Kinderknecht farm, seven miles southwest of Hays, during the summer of 1933. An adult was also taken on the same farm in a culvert on May 16, 1934.

FROGS

Rana pipiens (Schreber). Leopard frog. Very common in pasture ponds and streams.

Acris gryllus (LeConte). Cricket frog. Very numerous in pasture ponds and streams.

Pseudacris nigrita triseriata (Wied). Swamp cricket frog. Some 30 specimens were taken on the Steve Sack and A. Truan farms from pasture ponds in the summer of 1931. None were collected in 1933, possibly due to the extreme dryness of the season.

Scaphiopus hammondi bombifrons Baird. Spadefoot toad. A very small specimen was brought into the laboratory on May 9, 1931, and given to Mr. L. D. Wooster, who made the proper identification. A specimen was taken from a house cat by the writer on May 7, 1934.

Gastrophryne olivacea Hallowell. Narrow-mouthed toad. One of these toads was found at night on the top of Yocemento hill, seven miles west of Hays, and one under a flat rock on a hillside on the Steve Sack farm, five miles west of Hays. These are the first specimens of this species that have been found in this region.

Bufo cognatus Say. Western toad. Not common in this territory; two specimens were taken on the campus at St. Joseph's College, Hays, during the summer of 1933.

Bufo woodhousii woodhousii (Girard). Woodhouse's toad. The most common toad in the county, found in gardens, in fields and under street lamps at night.

Rana catesbeiana (Shaw). Bullfrog. Common in permanent ponds.

TURTLES

Chelydra serpentina (Linnæus). Snapping turtle. Common. A nest of 24 eggs was found in a bank of Big creek on August 9, 1933, and about three weeks later 23 of the eggs hatched.

Amyda spinifera (LeSueur). Soft-shelled turtle. Five small specimens were taken below a dam on Big creek on June 10, 1933. Two large specimens were taken from Big creek on November 26, 1933.

Kinosternon flavescens (Agassiz). Yellow-necked mud turtle. Rather common in muddy ponds and in the Smoky Hill river in the southern part of the county. One is reported from the Saline river in the northern part of the county by Mr. L. D. Wooster.

Terrapene ornata (Agassiz). Box tortoise. Common, especially in the sandy areas along the rivers. Farmers report that considerable destruction of cantaloupes is caused by this species. They bite holes in the ends of the melons. On June 27, 1933, three observers counted thirty in less than one-half hour in an area near a melon patch near the Smoky Hill river. On June 24, 1911, 26 individuals, 14 of which were females, were observed along the sandy shores of the Saline river.

Chrysemys bellii bellii (Gray). Painted terrapin. Extremely common in permanent ponds and streams. On one field trip to the Truan farm, eight miles north of Hays, 54 individuals were counted in the pasture ponds.

LIZARDS

Crotaphytus collaris (Say). Collared lizard. Common under flat rocks on prairie hillsides. On April 18, 1934, six specimens were found, of which four were very stiff and inactive, probably still hibernating.

Phrynosoma cornutum (Harlan). "Common horned toad." On and near rocky hills.

Phrynosoma douglassii hernandesi (Girard). Short-horned lizard. A single specimen is in the museum of the Fort Hays Kansas State College. On this basis Burt has recorded this form from Ellis county in his "Lizards of Kansas." (Trans. St. Louis Acad. Sci., 26:1-81. 1928.)

Sceloporus undulatus consobrinus (Baird and Girard). Spiny swift. Common.

Holbrookia maculata maculata (Girard). Spotted sand swift. Common.

Ophisaurus ventralis (Linnæus). "Glass snake." Two specimens are in the museum at the Fort Hays Kansas State College. Occasionally they are reported as being seen locally.

Cnemidophorus sexlineatus sexlineatus (Linné). Six-lined race-runner. Common along the railroads and in sanded areas. Three specimens were found hibernating under a flat rock on April 16, 1934.

Eumeces obsoletus (Baird and Girard). Sonoran skink. Found in flat rock areas. Rather easy to collect in the spring, but hard to secure later.

SNAKES

Tantilla gracilis nigriceps (Kennicott). Mitre snake. Common. Eight were taken under one flat rock.

Thamnophis sauritus proximus (Say). Western ribbon snake. Two specimens are in the Museum of the Fort Hays Kansas State College. They were taken from Big creek in the summer of 1933.

Thamnophis radix radix (Baird and Girard). Plains garter snake. Common, mostly about pasture ponds rather than streams.

Thamnophis lineatus (Hallowell). Lined snake. This small snake seems to be rare, or at least it is difficult to find. One specimen was taken under a rocky ledge, near the bottom of a rocky hill near Schoenchen. Other specimens have been found just beyond the county line in Russell county.

Sonora semiannulata (Baird and Girard). This species was found over the county line in Russell county by Leo Brown, on April 22, 1932. This is the first record of this species within this area.

Lampropeltis triangulum gentilis (Baird and Girard). Banded king snake. Common.

Lampropeltis getulus holbrooki (Stejneger). Say's king snake. The salt and pepper snake is common.

Lampropeltis calligaster (Harlan). Prairie king snake. Not common.

Pituophis sayi sayi (Schlegel). Bull snake. Specimens were taken during each summer, this being our most common and best-known land snake.

Elaphe læta (Baird and Girard). Rat snake. Found frequently in early spring under flat rocks. On April 30, 1932, 30 specimens were taken just across Russell county line, in flat-rock area.

Masticophis flagellum flagellum (Shaw). Western coachwhip. Usually found in open prairie country. A specimen laid eggs while in captivity at Fort Hays Kansas State College, on July 4, 1932.

Coluber constrictor flaviventris (Say). Blue racer. Common.

Heterodon nasicus (Baird and Girard). Hog-nosed snake. Common in sandy areas.

Heterodon contortrix (Linné). Hog-nosed snake. Common.

Diadophis punctatus arnyi (Kennicott). Ring-necked snake. On April 13, 1932, 14 were taken under a flat rock near Schoenchen.

Natrix sipedon sipedon (Linné). Brown water snake. A common snake found in streams and under flat rocks near and in the water.

Crotalus confluentus confluentus (Say). Prairie rattler. In the summer of 1933 eleven specimens were taken in the prairies of this area. Reported to be more numerous in 1933 than in 1932.

Additional Records of the Reptiles of the Central Prairie Region of the United States

CHARLES E. BURT and WILLIAM LUTHER HOYLE, Southwestern College, Winfield, Kan.

Data for the present contribution has been gathered during numerous field expeditions in the Middle West particularly from 1931 to 1933. Original observations have been made on the habitats and habits of certain species, and many county records are added to the known range of numerous forms.

The area covered by this report includes sections of Indiana, Illinois, Iowa, Missouri, Arkansas, Oklahoma, Kansas, Nebraska, South Dakota and Wyoming; but the major portion deals with the herpetology of Kansas, Nebraska and Oklahoma, with especial reference to Kansas.

The specimens involved in our study have been widely distributed to museums and individuals, both at home and abroad, but most of them are deposited in places where they are readily available for further study. Friends, collectors, and correspondents (exclusive of students at Southwestern College), who have collected specimens presented herein, are listed as follows: F. M. Adams, J. A. Allen, Leo Brown, Waunita Burchell, David Dunkle, Max Elias, Edith R. Force, Howard K. Gloyd, Charles Hadley, Daniel Hink, Charles Keech, W. S. Long, Harold Lyon, Horace Lyon, George Jelinek, Paul McGrew, Roy L. Moodie, Richard Nelson, C. B. Perkins, Alvin Peterson, E. F. Powell, Theodore Robb, Ottys Sanders, Dorothy Schreck, Hobart M. Smith, Edward H. Taylor, E. C. Thayer, Samuel Tihen, Robert H. Wolcott, and G. A. Whitney. Data have been obtained from specimens at the University of Nebraska through the courtesy of Dr. Otis Wade and Mr. E. F. Powell; at Kansas State College through Dr. Robert K. Nabours and Mr. M. J. Harbaugh; and at Southern Methodist University through Dr. S. W. Geiser and Dr. Elmer P. Cheatum.

The following students of Southwestern College have collected reptiles that are discussed in this report: Byard Anderson, Phil Antrim, Keith Corp, Clayton Gerboth, Victor Edgell, Clay Hildinger, Cornelius Rogers, Don Strother, Esther Stuber, and Merlin Trumbull.

Before presenting the discussion of species, something may be said pertaining to the systematic arrangement of the larger reptilian groups. In all three editions of their "Check List of North American Amphibians and Reptiles," Stejneger and Barbour (1917, 1923, 1933) have stated that their "higher groups and genera are in systematic sequence." With reference to the subclasses and orders of reptiles, the following arrangement has been maintained in all three editions (following Osborn, 1903):

- I. Subclass Diapsida.
  - A. Order Loricata (crocodile and alligator).
  - B. Order Squamata (lizards and snakes).
- II. Subclass Synapsida.
  - A. Order Testudinata (turtles).

The examination of modern publications in the field of paleontology by such authorities as Williston (1925), Berry (1929), and Romer (1933a-b),

indicates that the systematic sequence adopted in the North American Check List is not in accord with the known facts in the case, and that additional subclass names can be applied with a fair degree of certainty to the known reptilian aggregations. The modern outline of classification, as applied to the groups cited by Stejneger and Barbour, would be as follows:

I. Subclass Anapsida.
   A. Order Testudinata (turtles).
II. Subclass Parapsida.
   A. Order Squamata (lizards and snakes).
III. Subclass Diapsida.
   A. Order Loricata (crocodile and alligator).

Osborn used the name Synapsida to include the primitive reptiles now placed in the reptilian subclasses Anapsida and Synapsida, and Stejneger and Barbour have used the name "Synapsida" in connection with the turtles, but they have placed the group above the other modern reptiles in their phyllogenetic scheme. In contrast to modern American workers in general, such European herpetologists as Mocquard, Parker, Bolkay, Werner, Mertens and Mueller, have placed the Testudinata at the beginning of systematic lists of reptiles in a "primitive or early-derived" position. This latter action is in accord with paleontological findings. The turtles are placed in the Subclass Anapsida by Williston and Romer, along with the primitive Order Cotylosauria, with which they agree in having the skull completely roofed over (temporal opening absent) and in having the feet spread widely apart, just as they were in their sprawling stegocephalian ancestors.

Adams (1933) placed the turtles in the modern subclass Synapsida, which has a lower temporal opening in the skull beneath the postorbito-squamosal arch, stating (p. 191) that it is possible that the turtles have a "secondary roof which resembles the Cotylosaurs." Romer, on the other hand, placed the turtles in the Anapsida, since it is "probable that they have retained the primitive solid skull roof." The status of the turtles, with respect to subclass, involves some uncertainty, perhaps, but there seems to be no question as to the primitive nature of the group as compared with that of the modern Parapsida and Diapsida.

The subclass Diapsida of Osborn (and of Stejneger and Barbour) includes the modern subclasses Parapsida and Diapsida. The Parapsida have an upper temporal opening present in the skull, while the Diapsida have both upper and lower temporal openings.

Therefore, the lizards and the snakes are parapsids and the crocodiles and alligators are diapsids. These two subclasses may be polyphyletic, as suggested by the phylogenetic trees produced by Romer (1933b), and in this case a more substantial arrangement (based on new characters) may be forthcoming. The Diapsida are technically more specialized than the Parapsida, although many of the modern lizards and snakes are as specialized as the Loricata in average features.

LIST OF SPECIES

WITH NOTES AND COUNTY RECORDS

TURTLES

Sternotherus odoratus (Latereille)

A young representative of this form was taken in a seine from the wooded Sandy creek, a branch of the Verdigris river, in southern Woodson county, Kansas, at a point 5½ miles northeast of Coyville (June 27, 1931).

Kinosternon flavescens (Agassiz)

These turtles are regular denizens of many of the ponds and sluggish streams within their range. They often have algæ on their backs, and they frequently bask in the sun near the water's edge. Individuals sometimes leave the water to forage on the land, and such activity becomes especially generalized during rainy periods.

KANSAS.

BARBER: 7 mi. S. Sun City (Smith, September 4, 1933).
CLARK: Bluff Creek, 10 mi. E. Ashland (Smith, July 24, 1933); 2 mi. S. Englewood (Smith, July 24, 1933).
COMANCHE: Bluff creek, 15 mi. E. Ashland (Smith, July 24, 1933).
ELLSWORTH: County line west of Brookville (Smith, 1932).
KINGMAN: Kingman (Smith, September 9, 1933).
KIOWA: 7 mi. S. Belvidere (Smith, September 4, 1933).
MEADE: 7 mi. W. Englewood (Smith, July 23, 1933).
SUMNER: 1 mi. E. Conway Springs (Smith, September 8, 1933).

NEBRASKA.

NUCKOLLS: 1 mi. W. Superior (Burt, May 14, 1933).

OKLAHOMA.

BECKHAM: 4 mi. S. W. Sayre (Hoyle, June 10, 1933).

Chelydra serpentina (Linnæus)

On August 9, 1933, Miss Virginia Stuber found 14 eggs of this species in the mud at the edge of Black creek, near Winfield, Cowley county, Kansas. The mass of eggs was drying out, but there had been plenty of moisture present for their development. All of the shells were "pipped," but the young snappers were dead in six of the eggs. Those in the other eight hatched on the same day as they were found (August 9), remaining alive, and living to carry on the normal routine of acquarium denizens. With the approach of colder weather in November and December, these young captives buried themselves in the mud and sand at the bottom of their laboratory home, but occasionally one of them was seen in a more or less exposed position after the water was changed in the acquarium (January and February, 1934).

ILLINOIS.

PEORIA: 11 mi. S. W. Peoria (Burt, June 4, 1933).

KANSAS.

COMANCHE: Schwartz Canyon near Arrington (Smith, September 5, 1933).
COWLEY: Black creek, 1 mi. S. E. Winfield (Stuber, August 9, 1933).
CRAWFORD: 4 mi. S. Pittsburg (Burt, July 27, 1931).
OSAGE: 2 mi. S. Barclay (Burt, June 8, 1933).
SALINE: 4 mi. W. Gypsum (Hoyle, May 14, 1933).

SHAWNEE: 5 mi. E. Dover (Burt, May 18, 1933); 8 mi. E. Pauline (Smith, September 10, 1933).
SUMNER: Ninnescah river, 8 mi. S. Belle Plaine (Hoyle, July 15, 1932).
WABAUNSEE: 3 mi. E. Paxico (Burt, May 18, 1933).

MISSOURI.
BUCHANAN: East Atchison, near Missouri river (Burt, June 8, 1933).
JASPER: 2 mi. S. Asbury (Burt, June 27, 1931).
LIVINGSTON: 6 mi. W. Utica (Burt, June 4, 1933).

NEBRASKA.
KNOX: 5 mi. S. W. Crofton (Burt, August 9, 1931).

Emys blandingii (Holbrook)

The capture of a representative of this species (U. S. N. M. No. 86794) on the road above a shallow pond 2 mi. S. of Pilger, Stanton county (Burt, August 3, 1932), apparently constitutes the first record of the occurrence of *Emys blandingii* in Nebraska. At the time of collection the specimen was recognized as unique to the Middle West, so it was forwarded to Dr. Leonhard Stejneger, who kindly sent the above identification.

Terrapene triunguis (Agassiz)

Like the common ornate terrapin or box turtle, this species frequents the highways along its range, especially during the morning hours—when many of them are killed by automobiles.

ARKANSAS.
PERRY: 6 mi. W. Casa (Burt, June 29, 1931).

KANSAS.
CHEROKEE: Spring river, about 2 mi. N. Baxter Springs (Taylor, April 4, 1931).

MISSOURI.
CRAWFORD: 1 mi. N. E. Hofflins (Burt, August 31, 1933).
FRANKLIN: 2 mi. W. Leslie (Burt, August 29, 1933).
GASCONADE: 1 mi. W. Drake (Burt, August 29, 1933).
LACLEDE: 2 mi. S. Lebanon (Burt, August 31, 1933).

Terrapene ornata (Agassiz)

Ornate box turtles are most often found in grassy areas of the Middle West, but they may occur in the light woods as well. Thousands of individuals are, no doubt, crushed on the highways each year, as they are caught sunning themselves or foraging on road clearings adjacent to their natural habitats. Box turtles in search of food may be seen to snap at insects, especially grasshoppers, when occasion offers.

KANSAS.
BARBER: 4 mi. E. Lake City (Smith, September 2, 1933); 7 mi. S. Sun City (Smith, September 4, 1933).
CHASE: 3 mi. S. Cottonwood Falls (Burt, May 12, 1933); 5 mi. N. Strong City (Hoyle, May 12, 1933).
CHAUTAUQUA: 2 mi. S. E. Cedarvale (Hoyle, July 30, 1933).
CHEROKEE: 8 mi. E. Weir (Burt, June 27, 1931).
COFFEY: 1 mi. N. Lebo (Burt, June 8, 1933).
COMANCHE: Arrington (Smith, September 5, 1933).
COWLEY: 1 mi. N. E. Cambridge (Burt, April 22, 1933); 6 mi. N. E. New Salem (Hoyle, July 18, 1933); 2 mi. S. E. New Salem (Hoyle, July 18, 1933).

CRAWFORD: 4 mi. S. Pittsburg (Burt, June 27, 1931).
DICKINSON: 2 mi. N. W. Abilene (Smith, 1932).
ELK: 4 mi. N. Moline (Burt, June 3, 1933).
ELLSWORTH: County line E. Brookville (Smith, 1932); 4 mi. N. E. Carneiro (Hoyle, May 14, 1933).
FORD: 8 mi. E. Dodge City (Trumbull, May 7, 1933).
GEARY: 1 mi. S. W. Junction City (Hoyle, May 15, 1933).
GREENWOOD: 1 mi. N. Severy (Burt, June 3, 1933); 2 mi. N. Tonovay (Burt, June 8, 1933).
HARPER: Cimarron river, just S. Englewood (Smith, July 23, 1933).
KINGMAN: 10 mi. W. Conway Springs (Smith, September 8, 1933); Kingman (Smith, September 9, 1933).
LYON: 2 mi. N. E. Miller (Hoyle, May 13, 1933).
MARION: 6 mi. S. Florence (Burt, May 15, 1933).
MEADE: Cimarron river, 35 mi. S. E. Meade Co. State Park (Smith, July 22, 1933).
OSAGE: 7 mi. N. Burlingame (Hoyle, May 13, 1933).
SCOTT: State Park (Smith, July 21, 1933).
SHAWNEE: 7 mi. N. E. Dover (Burt, May 13, 1933).
SUMNER: Argonia (Burt, October 14, 1933); 2 mi. S. W. Dalton (Hoyle, July 18, 1933); 6 mi. W. Oxford (Burt, June, 1931).
WABAUNSEE: 4 mi. E. Maplehill (Hoyle, May 13, 1933).

MISSOURI.
CALDWELL: 4 mi. E. Hamilton (Burt, June 4, 1933).
JASPER: 1 mi. E. Asbury (Burt, June 27, 1931); 1 mi. S. Asbury (Burt, June 27, 1931).
MACON: 1 mi. W. Lingo (Burt, June 4, 1933).

NEBRASKA.
SHERIDAN: 2 mi. E. Hoffland (Burt, August 17, 1931).

OKLAHOMA.
BECKHAM: 4 mi. S. W. Sayre (Hoyle, June 10, 1933).
CARTER: 3 mi. S. Ardmore (Burt, May 30, 1931).
GREER: 3 mi. N. Blair (Hoyle, June 10, 1933); 9 mi. N. W. Blair (Hoyle, June 10, 1933).
KAY: 6 mi. N. E. Newkirk (Burt, April 29, 1933).

Graptemys pseudogeographica pseudogeographica (Gray)

One of these keel-backed terrapins from Manila, Mississippi county, Arkansas, has been kindly presented to us by Mr. Ottys Sanders of the Southwestern Biological Supply House (1931).

Chrysemys bellii bellii (Gray)

Records for the painted terrapin of the Middle West are presented below.

KANSAS.
COWLEY: 1 mi. E. New Salem (Hoyle, July 18, 1933).
ELLSWORTH: County line, W. Brookville (Smith, 1932).
SALINE: 4 mi. W. Gypsum (Burt, May 14, 1933).
SCOTT: State Park (Smith, September 21, 1933).
WOODSON: 9 mi. E. Toronto (Burt, July 27, 1931).

MISSOURI.
BUCHANAN: East Atchison, near Missouri river (Burt, June 3, 1933).

NEBRASKA.
LANCASTER: 5 mi. S. Lincoln (Corp, September 27, 1933).

Pseudemys elegans (Wied)

This turtle inhabits the larger streams and ponds of the Middle West.

ARKANSAS.

MISSISSIPPI: Manila (Sanders, 1931).

KANSAS.

COMANCHE: Mouth of Schwartz Canyon on Indian river (Smith, September 5, 1933).

ELK: 2 mi. N. Grenola (Hoyle, August 3, 1933).

OKLAHOMA.

CARTER: 3 mi. N. Ardmore (Burt, April 18, 1932).

LOVE: U. S. Highway No. 77 at 1 mi. N. Red river bridge (Burt, April 18, 1932).

Pseudemys texana (Baur)

Two of these turtles from Manila, Mississippi county, Arkansas, have been given to us by Mr. Ottys Sanders (1931), and a young specimen was taken in a seine at Sandy creek, a branch of the Verdigris river, at a point 5½ miles northeast of Coyville, in southern Woodson county, Kansas (Burt, June 27, 1931).

Amyda spinifera (Le Sueur)

Our records for this soft-shelled turtle are listed below.

KANSAS.

BARBER: 7 mi. S. Sun City (Smith, September 2, 1933).

BUTLER: 8 mi. S. E. Augusta (Hoyle, May 15, 1933).

COMANCHE: 4 mi. S. E. Arrington (Smith, September 5, 1933).

COWLEY: Walnut river, 1 mi. W. Winfield (Trumbull, April 30, 1933).

LOGAN: 8 mi. S. W. Elkader (Moodie, July, 1911).

LIZARDS

Crotaphytus collaris (Say)

After a large collared lizard was chased down a steep hill in Elk county, Kansas, on April 22, 1933, it dived into a pool of muddy water, where it hid in complete submergence beneath a small flat rock in an attempt to escape detection and capture.

In the early spring several individuals are often found under one rock, and sometimes these are a pair of adults, as in the case of two examples found in a hollow depression under a stone in Oklahoma county, Oklahoma, on March 15, 1932.

Under a flat rock, which was less than an inch in thickness and about two feet square, a female of this species was found in shallow burrow on May 28, 1932. A nest of 16 ovoid eggs was located at the end of this depression. These eggs, which were loosely packed in moist earth, were partially exposed to the lower surface of the rock, which in turn was subjected to the direct rays of the sun. Examination of three of the eggs showed two of them to contain small embryos.

Specimens have been taken as follows:

KANSAS.

BARBER: 2 mi. N. Lake City (Rogers, October 16, 1933).

BUTLER: 1 mi. N. Beaumont (Smith, September 9, 1933).

CHASE: 6 mi. S. Cottonwood Falls (Burt, May 12, 1933); 2 mi. W. Cottonwood Falls (Smith, September 1, 1933).

CHAUTAUQUA: 1 mi. E. Cedarvale (Burt, April 3, 1933); 3 mi. W. Peru (Hoyle, April 3, 1933).
CLOUD: Miltonvale (Smith, April 8, 1933).
COWLEY: 1 mi. N. E. Cambridge (Burt, April 22, 1933); 2 mi. N. W. Cameron (Burt, May 6, 1933); 1 mi. N. Maple City (Hoyle, May 6, 1933); 1 mi. N. Rock (Hoyle, May 12, 1933).
ELK: 3 mi. E. Moline (Burt, April 22, 1933).
ELLSWORTH: 4 mi. E. Carneiro (Burt, May 14, 1933).
GEARY: 1 mi. S. W. Junction City (Hoyle, May 15, 1933).
HARPER: 5 mi. S. Harper (Tihen, July, 1933).
LINCOLN: 10 mi. S. W. Lincoln (Burt, May 14, 1933).
MITCHELL: 10 mi. S. Beloit (Hoyle, May 14, 1933).
MONTGOMERY: 5 mi. N. E. Elk City (Burt, April 22, 1933).
WABAUNSEE: 7 mi. N. Alma (Hoyle, May 13, 1933); 3 mi. S. E. Wabaunsee (Burt, May 13, 1933).

OKLAHOMA.

KAY: 6 mi. S. E. Chilocco (Burt, April 29, 1933); 6 mi. N. E. Newkirk (Hoyle, April 29, 1933).
LOGAN: 2 mi. N. Mulhall (Burt, April 15, 1932).
OKLAHOMA: 7 mi. N. Oklahoma City (Burt, April 15, 1932).
OSAGE: 2 mi. S. E. Avant (Burt, April 23, 1933); 10 mi. S. W. Bartlesville (Hoyle, April 3, 1933); 4 mi. W. Pawhuska (Burt, April 3, 1933).
ROGERS: 6 mi. W. Claremore (Hoyle, April 23, 1933).

Holbrookia maculata maculata (Girard)

These spotted lizards are characteristic inhabitants of sandy areas, where they may seek shelter in holes among the roots of rose bushes or other shrubs, or in grass clumps. Young examples taken in Nebraska on August 18 and 19, 1931, were no doubt of the brood of that year.

KANSAS.

BARBER: 7 mi. S. Sun City (Smith, September 2, 1933).
BUTLER: 1 mi. W. Keighly (Smith, September 9, 1933).
COMANCHE: Schwartz Canyon, near Arrington (Smith, September 6, 1933).
HARPER: Cimarron river, S. Englewood (Smith, July 22, 1933).
KINGMAN: 5 mi. W. Norwich (Smith, September 8, 1933); 4 mi. W. Spivey (Antrim, October 29, 1933).
SUMNER: Argonia (Tihen, August 23, 1933).

NEBRASKA.

CHERRY: 6 mi. N. E. Cherry (Burt, August 18, 1931); 7 mi. S. E. Gard (Burt, August 18, 1931); 9 mi. N. W. Wood Lake (Burt, August 18, 1931); 3 mi. S. E. Valentine (McGrew, July, 1933).
GRANT: 2 mi. E. Whitman (Burt, August 18, 1931).
SHERIDAN: 2 mi. E. Bingham (Burt, August 19, 1931); 2 mi. W. Bingham (Burt, August 19, 1931).

Sceloporus graciosus graciosus (Baird and Girard)

As noted by Van Denburgh in 1922, the range given by Stejneger and Barbour for this subspecies largely overlaps the one listed for *S. undulatus consobrinus*, and it is evident that in the west *graciosus* has at times been considered as *consobrinus* and that in the east the opposite is true. This is not surprising, since the coloration, scutellation and size of the two forms compares favorably in most respects. However, the keels are less pronounced on the dorsal and lateral scales of *graciosus* (especially on the back of the thighs) as discerned by Van Denburgh. Since all morphological distinctions are slight, the ranges adjacent, and the resemblances marked, a close relationship is

indicated for the two forms and it is very probable that *graciosus* and its subspecies arose in rather recent geological times from common ancestral stock with members of the *undulatus* complex (such as *consobrinus* and *elongatus*).

The morphological differentiation between *consobrinus* and *graciosus* may be summarized as follows:

Scales from the occiput to the base of the tail, 36-48; scales on back of thigh usually keeled; adult males often with a distinct blue spot at each side of the chin (Dakotas, south to Texas; also, eastern Colorado and Wyoming).
S. undulatus consobrinus Baird and Girard

Scales from the occiput to the base of the tail, 40-55; most of scales on back of thigh smooth; adult males usually with a grayish or bluish mottling on the throat, but sometimes with noticeable blue concentrations at each side of chin (eastern Oregon to central Montana, south through east-central Wyoming and western Colorado to northern Arizona, and northwest through Nevada to eastern Oregon).
S. graciosus graciosus Baird and Girard

A specimen of *consobrinus* in the present collection from Goshen county, Wyoming, has 41 scales from the occiput to the base of the tail, which is a high figure for this form, but it would be a low one in the variational range of *graciosus*. Scale data in the above key are after Van Denburgh, our Wyoming specimens fitting within the extremes given by him.

S. graciosus graciosus exhibits sexual dimorphism in the coloration, in that all markings tend to be more distinct in the adult male than in the adult female. The adult male shows beautiful bright-blue belly patches, which are separated along the median ventral line, but in the young males and in the females these are indistinct or absent.

This spiny swift is a characteristic inhabitant of the rock ledges which are present in the arid foothill country of central and western Wyoming. In this environment sage brush constitutes the dominant form of plant life, although short clumps of grass are often present. On sunny days these creatures are very active in favorable habitats, where they forage on and about the rocks among which they live, darting into crevices when danger threatens. In a few instances individuals were found in brush below rock ledges.

WYOMING.

FREMONT: 14 mi. S. E. Dubois (Burt, August 13, 1931); 8 mi. E. Riverton (Burt, August 13, 1931); 7 mi. E. Shoshoni (Burt, August 13, 1931); 14 mi. E. Shoshoni (Burt, August 13, 1931).

NATRONA: 11 mi. N. W. Teapot Dome, at N. edge Midwest Oil Field (Burt, August 16, 1931).

WASHAKIE: 7 mi. W. Ten Sleep (Burt, August 16, 1931).

Sceloporus undulatus consobrinus Baird and Girard

These prairie swifts occur in sandy or rocky areas, usually near thickets of shrubbery. On April 30, 1933, individuals observed in Cowley county, Kansas, darted for shelter in holes at the base of the yucca plants. Some of these holes were very deep, offering the lizards ample protection from large enemies, but others were too shallow to afford security.

KANSAS.

BARBER: 4 mi. E. Lake City (Smith, September 2, 1933); 2 mi. N. Lake City (Rogers, October 16, 1933); 7 mi. S. Sun City (Smith, September 2, 1933).

COMANCHE: Bluff creek, 15 mi. E. Ashland (Smith, July 24, 1933).

COWLEY: 11 mi. S. W. Winfield (Hoyle, April 30, 1933).

HARPER: 1 mi. N. Harper (Tihen, August 5, 1933); 4 mi. N. and 8 mi. E. Harper (Tihen, August 23, 1933).

KINGMAN: 5 mi. W. Norwich (Smith, September 8, 1933); 4 mi. W. Spivey (Antrim, October 29, 1933).
McPHERSON: Battle Hill (Burt, May 12, 1926).
SCOTT: State Park (Smith, July 21, 1933).
SUMNER: Argonia (Tihen, August 28, 1933).

NEBRASKA.
CHERRY: 3 mi. S. E. Valentine (McGrew, July, 1933).

OKLAHOMA.
OSAGE: 7 mi. W. Bartlesville (Burt, April 3, 1933); 3 mi. W. Pawhauska (Hoyle, April 3, 1933).

WYOMING.
GOSHEN: 2 mi. S. E. Lingle (Burt, August 17, 1931).

Sceloporus undulatus undulatus (Latreille)

Several records are at hand for Arkansas lizards of this subspecies. One individual climbed a tree to a point over eight feet above the ground 4 mi. N. of Pine Bluff, Jefferson county (June 29, 1931); an example from Louisville, Lafayette county, is preserved in the Museum of Kansas State College; and specimens were taken at the base of a pine tree near a pond at Hensley, and in the shrubbery near a broad, rocky stream 11 mi. S. E. of Maumelle, in Pulaski county (June 29, 1931).

Phrynosoma cornutum (Harlan)

A newly-captured female horned lizard from Cowley county, Kansas, laid seven yellowish eggs while it was kept in a sunny location at a window on June 5 and 6, 1933. Various individuals taken along a freshly tarred roadbed in Garfield county, Oklahoma, on June 9, had much tar on their feet and ventral surfaces. One besmeared specimen was found in a cotton patch about a quarter of a mile from the road.

KANSAS.
BARBER: 7 mi. S. Sun City (Smith, September 3, 1933).
CHASE: 2 mi. W. Cottonwood Falls (Smith, September 1, 1933).
COWLEY: 4 mi. E. Arkansas City (Burt, May 6, 1933); 1 mi. N. E. Cambridge (Hoyle, April 22, 1933); 6 mi. N. E. New Salem (Hoyle, July 18, 1933); 5 mi. S. Winfield (Hoyle, July 21, 1933).
ELK: 2 mi. N. W. Grenola (Harold Lyon, August 25, 1933).
GEARY: 1 mi. S. W. Junction City (Burt, May 15, 1933).
HARPER: 5 mi. S. Harper (Tihen, July, 1933).
LINCOLN: 10 mi. S. W. Lincoln (Burt, May 14, 1933).
SEDGWICK: Clearwater (Burchell, April, 1933).

OKLAHOMA.
BECKHAM: Elk City (Hoyle, June 9, 1933); Sayre (Hoyle, June 10, 1933); 4 mi. S. W. Sayre (Hoyle, June 10, 1933).
GARFIELD: 5 mi. S. Enid (Hoyle, June 9, 1933).
KINGFISHER: 1 mi. N. Bison (Hoyle, June 9, 1933).
PAWNEE: Pawnee (Thayer, 1895, K. S. C. Mus.).

Phrynosoma douglassii hernandesi (Girard)

One of these short-horned horned lizards was collected 3 mi. S. E. Valentine, Cherry county, Nebraska, in July, 1933, by Paul McGrew.

Ophisaurus ventralis (Linnæus)

In Cowley county, Kansas, the joint lizard occurs in the same general habitat as the common skink *Eumeces obsoletus,* selecting conditions with an average of more moisture than that required by the second common lizard of the prairie ledges, *Crotaphytus collaris.*

KANSAS.

COWLEY: Southwestern College Campus (Edgell, September 25, 1933); 9 mi. N. E. Winfield (Burt, May 7, 1933).
ELLSWORTH: Ellsworth (Jelinek, September 11, 1933).

Cnemidophorus sexlineatus sexlineatus (Linnæus)

A six-lined race-runner was chased into a stream in Beckham county, Oklahoma, on June 10, 1933, where it escaped by swimming from one bank to the other (a distance of about 12 feet.)

ARKANSAS.

JEFFERSON: 4 mi. N. Pine Bluff (Burt, June 29, 1931).
MADISON: 2 mi. N. Crosses (Burt, June 28, 1931).
PULASKI: 4 mi. S. E. Maumelle (Burt, June 29, 1931).

KANSAS.

BARBER: 4 mi. S. E. Lake City (Smith, September 2, 1933).
ELLSWORTH: 5 mi. N. E. Carneiro (Burt, May 14, 1933); 3 mi. E. Ellsworth (Hoyle, May 14, 1933).
GEARY: 1 mi. S. W. Junction City (Hoyle, May 15, 1933).
HARPER: 4 mi. N. and 8 mi. E. Harper (Tihen, August 23, 1933).
KINGMAN: 6 mi. S. W. Norwich (Tihen, August 20, 1933).
LINCOLN: 10 mi. S. W. Lincoln (Burt, May 14, 1933).
SUMNER: Argonia (Tihen, August 23, 1933).

NEBRASKA.

CHERRY: 8 mi. S. E. Valentine (McGrew, July, 1933).

OKLAHOMA.

BECKHAM: 2 mi. S. E. Erick (Hoyle, June 10, 1933); 4 mi. S. W. Sayre (Hoyle, June 10, 1933).
KAY: 6 mi. N. E. Newkirk (Burt, April 29, 1933).
OSAGE: 4 mi. W. Pawhuska (Hoyle, April 8, 1933).

Leiolopisma laterale (Say)

The specimens listed below were taken in or near woods, often under stones, bark, pieces of tin, or other sheltering debris.

ARKANSAS.

PULASKI: Granite Mt. near Little Rock (Adams, August 26, 1927, S. M. U. Mus.).

KANSAS.

CHEROKEE: 3 mi. N. Baxter Springs (Smith, April 4, 1931).
CLAY: Clay Center (Smith, April 9, 1933).
POTTAWATOMIE: Flush (Smith, April 16, 1933); Wheaton (Taylor, April 9, 1933).
WILSON: 4 mi. W. Neodesha (Burt, April 22, 1933).

OKLAHOMA.

CRAIG: 4 mi. S. W. Whiteoak (Burt, April 23, 1933).
CREEK: Bald Hill near Sapulpa (Force, April 2, 1932).
ROGERS: 6 mi. W. Claremore (Burt, April 23, 1933).

Eumeces anthracinus (Baird)

One of these skinks, with no postmental scale and with no postnasal scale, was secured by F. M. Adams on Granite Mountain, near Little Rock, Pulaski county, Arkansas, on August 26, 1927 (S. M. U. Mus.). The specimen shows no trace of a middorsal stripe.

Eumeces fasciatus (Linnæus)

These skinks are often found under rocks, wood, bark or pieces of tin in the woods of eastern Kansas and eastern Oklahoma.

KANSAS.

CHEROKEE: 3 mi. N. Baxter Springs (Taylor, April 4, 1931).
ELK: 3 mi. N. W. Oak Valley (Burt, April 22, 1933).
LABETTE: Labette Ozarks near Mortimer (Hoyle, April 22, 1933).

OKLAHOMA.

CRAIG: 4 mi. S. W. Whiteoak (Burt, April 28, 1933).
CREEK: Bald Hill near Sapulpa (Force, April 2, 1932).
ROGERS: 6 mi. W. Claremore (Burt, April 28, 1933).

Eumeces multivirgatus (Hallowell)

A young, many-lined skink was secured in the sandhill region 2 mi. W. Bingham, Sheridan county, Nebraska, on August 18, 1931, where it was associated with the newly-hatched young of *Holbrookia maculata maculata*. The young of both of these species were protected here by clusters of grass and weeds, but there were no rocks.

Eumeces obsoletus (Baird and Girard)

An adult Sonoran skink with an adult northern skink (*Eumeces septentrionalis*) in its stomach was secured in Morris county, Kansas, on May 14, 1933.

KANSAS.

BUTLER: 1 mi. N. E. Chelsea (Hoyle, May 12, 1933).
CHASE: 3 mi. S. Cottonwood Falls (Burt, May 12, 1933); 5 mi. N. Strong City (Hoyle, May 2, 1933).
CLAY: Clay Center (Taylor, April 9, 1933).
COWLEY: 1 mi. N. E. Cambridge (Hoyle, April 22, 1933); 1 mi. N. Rock (Burt, May 12, 1933).
ELK: 3 mi. E. Moline (Burt, May 22, 1933).
ELLSWORTH: 4 mi. E. Carneiro (Hoyle, May 14, 1933).
GEARY: 1 mi. S. W. Junction City (Burt, May 15, 1933).
JEWELL: 3 mi. S. E. Mankato (Hoyle, May 14, 1933).
LINCOLN: 10 mi. S. W. Lincoln (Burt, May 14, 1933).
MARION: 2 mi. W. Marion (Hoyle, May 15, 1933).
MITCHELL: 10 mi. S. Beloit (Burt, May 14, 1933).
MORRIS: 9 mi. S. W. Council Grove (Hoyle, May 15, 1933); 6 mi. E. Council Grove (Burt, May 14, 1933).
OSAGE: 7 mi. N. Burlingame (Burt, May 13, 1933).
POTTAWATOMIE: 2 mi. N. E. Rocky Ford (Hoyle, May 15, 1933).
SHAWNEE: 8 mi. W. Topeka (Burt, May 13, 1933).
WABAUNSEE: 7 mi. N. Alma (Hoyle, May 13, 1933); 5 mi. W. Maplehill (Burt, May 13, 1933); 3 mi. S. E. Wabaunsee (Hoyle, May 13, 1933).

OKLAHOMA.

KAY: 6 mi. N. E. Newkirk (Burt, April 29, 1933).
OSAGE: 2 mi. S. E. Avant (Hoyle, April 23, 1933); 4 mi. W. Pawhuska (Burt, April 8, 1933).

Eumeces septentrionalis (Baird)

A northern skink was found in the stomach of a Sonoran skink (*Eumeces obsoletus*) in Morris county, Kansas, on May 14, 1933.

The large adult male of this species has rose-colored patches over the cheeks and at the side of the gular region, reminding one of the coloration found in large adult males of *Eumeces tetragrammus* and *E. brevilineatus* in Texas. *E. septentrionalis* is found in the open prairie ledges of Kansas, where there are no trees, but where rocks and prairie grass offer much protection. Colonies of the northern skink are rather hard to find, but the form is often abundant where it occurs.

KANSAS.

CHASE: 8 mi. S. Cottonwood Falls (Hoyle, May 12, 1933); 6 mi. S. Cottonwood Falls (Burt, May 12, 1933).
MORRIS: 6 mi. E. Council Grove (Burt, May 14, 1933).
SHAWNEE: Berryton (Dunkle, April 14, 1933).
WABAUNSEE: 5 mi. W. Maplehill (Hoyle, May 13, 1933).

SNAKES

Carphophis amœna vermis (Kennicott)

A worm snake was collected under stones on a grassy hillside near a spring not far from Spring river and about 3 miles north of Baxter Springs, Cherokee county, Kansas, by Edward H. Taylor and Hobart M. Smith on April 4, 1931.

Diadophis punctatus arnyi Kennicott

Fifteen of these prairie, ring-necked snakes were found under one rock in Cowley county, Kansas, on April 8, 1933, and an unusual example was secured in Chase county, Kansas, on May 12, 1933. The latter specimen, which was taken under a rock on the bank of a small, sparsely wooded stream, exhibited the following characteristics: ventral plates, 177; caudals, 38; upper labials, 7 on each side; body length, 298 mm.; tail, 48 mm.; ventral spots in a single median row. Thus, the scutellation of *arnyi* is combined with a main colorational feature of the eastern *punctatus;* also, the lower surface of an additional example of *arnyi,* from Marion county, is almost spotless, thus offering a colorational approach to the northeastern *edwardsii.*

KANSAS.

CHASE: 8 mi. S. W. Matfield Green (Hoyle, May 12, 1933); 5 mi. N. Strong City (Burt, May 13, 1933).
CHAUTAUQUA: 1 mi. E. Cedarvale (Hoyle, April 3, 1933).
CHEROKEE: 3 mi. N. Baxter Springs (Taylor and Smith, April 4, 1931).
CLOUD: Miltonvale (Smith, April 8, 1933).
COWLEY: 10 mi. E. Winfield (Hildinger, April 8, 1933).
DICKINSON: 4 mi. N. W. Herington (Burt, May 14, 1933).
ELK: 3 mi. N. W. Oak Valley (Hoyle, April 22, 1933).
GEARY: 1 mi. S. W. Junction City (Burt, May 15, 1933).
LABETTE: Labette Ozarks near Mortimer (Burt, May 22, 1933).
MARION: 2 mi. W. Marion (Burt, May 15, 1933).
MARSHALL: 2 mi. S. Blue Rapids (Nelson, October 25, 1933).
MORRIS: 9 mi. S. W. Council Grove (Hoyle, May 12, 1933).
SHAWNEE: 8 mi. W. Topeka (Burt, May 13, 1933).
WILSON: 4 mi. W. Neodesha (Hoyle, April 22, 1933).

OKLAHOMA.

OSAGE: 2 mi. S. E. Avant (Burt, April 23, 1933); 4 mi. W. Pawhuska (Hoyle, April 8, 1933).

ROGERS: 6 mi. W. Claremore (Burt, April 23, 1933).

Heterodon contortrix (Linnæus)

This hog-nosed snake was found in an orchard in a sandy area in Cowley county on April 30, 1933, just as it was in the act of stalking a prairie swift (*Sceloporus undulatus consobrinus*). Damp sand was still on the snake's back and the snake's track was traced backward to the entrance of a hole about six feet away, where digging disclosed the den, which was about three feet long and about eight inches deep. The hole averaged about three inches in diameter.

KANSAS.

BARBER: 7 mi. E. Lake City (Rogers, October 16, 1933).

CLARK: Englewood (Hink, September 15, 1933).

COMANCHE: Arrington (Smith, September 8, 1933).

COWLEY: 11 mi. S. W. Winfield (Hoyle, April 30, 1933).

HARPER: Near Cimarron river directly south of Englewood (Smith, July 23, 1933); 4 mi. N. and 8 mi. E. of Harper (Tihen, August 23, 1933).

Heterodon nasicus Baird and Girard

This species occurs about sandy tracts in the prairie.

KANSAS.

DICKINSON: 2 mi. N. W. Abilene (Smith, 1932).

ELLSWORTH: County line W. Brookville (Smith, 1932).

NEBRASKA.

GRANT: 3 mi. W. Duluth (Burt, August, 1931).

Liopeltis vernalis (Harlan)

A smooth, green snake was collected at Camp Ta-la-hi 4½ miles southeast of Cedarvale, Chautauqua county, Kansas, on July 29, 1932 (Hoyle).

Opheodrys æstivus (Linnæus)

These relatively uncommon green snakes may be found under rocks in prairie ledges in the early spring, but later they are most likely to be located in vegetation, especially in shrubs and trees.

KANSAS.

CHAUTAUQUA: 4 mi. S. E. Cedarvale at Camp Ta-la-hi (Hoyle, July 24, 1932).

COWLEY: 5 mi. N. E. Arkansas City (Hoyle, July 6, 1931); 11 mi. S. E. Winfield (Hoyle, May 23, 1933); 7 mi. N. E. Winfield (Gerboth, April 12, 1933).

Coluber constrictor flaviventris Say

A blue-black phase of this subspecies, which offered a colorational approach to the eastern *constrictor*, was secured in Rogers county, Oklahoma, on April 4, 1933. Upon dissection, it was found to have an adult male collared lizard (*Crotaphytus collaris*) in its stomach.

KANSAS.

CHASE: 5 mi. N. Strong City (Burt, May 12, 1933).

CHEROKEE: 3 mi. N. Baxter Springs (Taylor and Smith, April 14, 1931).

CLARK: 4 mi. N. Englewood (Smith, July 24, 1933).

CLOUD: Miltonvale (Smith, April 8, 1933).

COFFEY: Lebo (Burt, June 3, 1933).

COWLEY: 3 mi. E. Cambridge (Burt, June 3, 1933).
ELK: 2 mi. N. W. Grenola (Horace Lyon, May 31, 1933); 3 mi. N. W. Oak Valley (Burt, April 22, 1933).
ELLSWORTH: 3 mi. E. Ellsworth (Hoyle, May 14, 1933).
GREENWOOD: 6 mi. S. Tonovay (Burt, June 3, 1933).
HARPER: 5 mi. S. W. Harper (Tihen, August 25, 1933).
JEWELL: 3 mi. S. E. Mankato (Hoyle, May 14, 1933).
LINCOLN: 10 mi. S. W. Lincoln (Burt, May 14, 1933).
POTTAWATOMIE: 2 mi. N. Westmoreland (Smith, April 9, 1933).
SUMNER: Argonia (Tihen, August 23, 1933).
WABAUNSEE: 1 mi. N. E. Alma (Hoyle, May 13, 1933); 7 mi. N. Alma (Burt, May 13, 1933).

MISSOURI.
JASPER: 6 mi. S. W. Blue Springs (Long, September 11, 1932).

NEBRASKA.
CHERRY: 3 mi. S. E. Valentine (McGrew, July, 1933).
NEMAHA: 6 mi. W. Johnson (Burt, June, 1931).

OKLAHOMA.
KAY: 6 mi. S. E. Chilocco (Hoyle, April 29, 1933).
ROGERS: 6 mi. W. Claremore (Burt, April 28, 1933).

WYOMING.
GOSHEN: 1 mi. S. E. Torrington (Burt, August 17, 1931).

Coluber flagellum flagellum Shaw

Kansas specimens of this subspecies occur about both open and wooded prairie ledges. The head and neck are deep blackish-brown, with the body becoming lighter posteriorly, and there may be poorly defined blotches on the back of some specimens.

KANSAS.
CHAUTAUQUA: 1 mi. E. Cedarvale (Gerboth, April 3, 1933).
COWLEY: 2 mi. N. W. Cameron (Burt, May 6, 1933); 7 mi. S. E. Winfield (Hoyle, April 18, 1933); 10 mi. E. Winfield (Hildinger, May 15, 1933).

MISSOURI.
PHELPS: 4 mi. N. E. Arlington (Burt, August 31, 1933).
PULASKI: 3 mi. E. Waynesville (Burt, August 31, 1933).

OKLAHOMA.
KAY: 6 mi. N. E. Newkirk (Burt, April 29, 1933).

Coluber flagellum flavigularis (Hallowell)

A prairie whipsnake with the preanal plate abnormally divided was found in Beckham county, Oklahoma, on June 10, 1933.

KANSAS.
BARBER: 1 mi. S. W. Aetna (Smith, September 6, 1933).
CLARK: Englewood (Hink, September 15, 1933).
SUMNER: Argonia (Tihen, August 23, 1933).

OKLAHOMA.
BECKHAM: 4 mi. S. W. Sayre (Hoyle, June 10, 1933).

Elaphe læta (Baird and Girard)

The young of this harmless prairie snake mimics like-sized individuals of the dwarf prairie rattlesnake (*Sistrurus catenatus catenatus*), which lives in the same general habitat, but to a careful observer differences (such as the presence or absence of a rattle and variation in the shape of the pupil of the eye) are

obvious. Mimicry is evidenced in the young of these two snakes by (1) the common possession of a shortened body, by (2) the exhibition of a series of dorsal blotches or saddles on a lighter background, and especially by (3) the extension of a conspicuous dark band through the eye. The same general idea of mimicry is conveyed by the resemblance of *Lampropeltis calligaster* to *Sistrurus*, but in this case the body of the former snake is slender enough to give a more definite off-hand clue as to its identity.

In Comanche county, Kansas, an *Elaphe læta* was secured in a gypsum cave, where it was hanging to slight irregularities of the roof.

KANSAS.

BARBER: 4 mi. S. Sun City in Dancer's Cave (Smith, September 4, 1933).
CHASE: 5 mi. N. Strong City (Burt, May 12, 1933).
COMANCHE: 2 mi. W. Aetna (Smith, September 7, 1933).
ELK: 2 mi. N. W. Grenola (Harold Lyon, July 31, 1933).
ELLIS: Hays (Brown, April, 1932).
JEWELL: 3 mi. S. E. Mankato (Burt, May 14, 1933).
LABETTE: Labette Ozarks near Mortimer (Hoyle, April 22, 1933).
OTTAWA: Ada (Smith, April 8, 1933).
SEDGWICK: Clearwater (Whitney, September 15, 1933).

OKLAHOMA.

GRANT: 1 mi. E. Medford (Hoyle, June 9, 1933).

Elaphe obsoleta (Say)

The supposed subspecies of this snake, *obsoleta* and *confinis*, appear to be Mendelian varieties at best, and there is a definite tendency for the production of more individuals of the *confinis* type in the young and the intermediate-sized females, as compared with the adult males, so ontogenetic blending exists and sexual dimorphism appears to influence the time of this transition. Extensive collecting experience has shown that (1) there is no habitat differentiation between the two varieties, that (2) they occupy the same range, and (3) that they show no evident contrasts in habits.

A moderate-sized female of this species (exhibiting the *confinis* color pattern) was discovered in the cupola of a barn near Grenola, Kan., on July 29, 1933. It was eating eggs from the nest of an English Sparrow (*Passer domesticus*). Later, the finding of the remains of an adult sparrow in the stomach of the snake indicated that the mother had possibly preceded her eggs in furnishing prospective nourishment to the snake.

KANSAS.

COWLEY: 2 mi. N. E. New Salem (Anderson, May 17, 1933).
ELK: 2 mi. N. W. Grenola (Hoyle, July 29, 1933); 3 mi. N. W. Oak Valley (Burt, April 22, 1933).
MARSHALL: 1 mi. E. Waterville (Burt, June, 1931).
POTTAWATOMIE: 4 mi. N. W. Olsburg (Hoyle, May 15, 1933).
SEDGWICK: 6 mi. W. Clearwater (Johnson, October, 1932).

MISSOURI.

JACKSON: Independence (Long, August 27, 1932).
MONROE: 3 mi. W. Lakenan (Burt, June 4, 1933).

Elaphe vulpina (Baird and Girard)

This snake is a typical inhabitant of the rolling prairie habitat that is so characteristic of the Upper Mississippi River Basin (above the Missouri river system). The coloration of this form resembles that of the southwestern *læta*.

ILLINOIS.

LA SALLE: 3 mi. E. Marseilles (Burt, June 9, 1931); 4 mi. E. La Salle (Burt, June 9, 1931).

WILL: 4 mi. N. Beecher (Burt, June 7, 1933).

IOWA.

BUCHANAN: 2 mi. E. Jesup (Burt, June 10, 1931).

UNION: 2 mi. E. Thayer (Burt, June 10, 1931).

NEBRASKA.

BURT: 3 mi. N. E. Lyons (Burt, June 2, 1931).

Arizona elegans elegans Kennicott

One of these snakes was secured 6 miles east of Erick, Beckham county, Oklahoma, on June 10, 1933 (Hoyle), in a sandy, sage-brush country. A second individual was taken 5 miles northeast of Canute, Washita county, Oklahoma (Hoyle, June 9, 1933), where it was in pasture land above a large lake. The first individual was a female with 10 large eggs in the right oviduct and none in the left.

Pituophis sayi sayi (Schlegel)

Bullsnakes are common in the prairie region of the Middle West, where they frequent areas of grassland, alfalfa and clover fields, cornfields, and cultivated areas in general. They are found not only in the less arid parts of the sandhills of Nebraska and South Dakota, but also in the irrigated lands of Wyoming, which lie immediately adjacent to extensive sage-brush desert.

The fine series of these snakes from Wyoming, listed below, has been carefully compared with examples from more eastern localities and there seems to be no ground for the taxonomic separation of the two adjacent populations. Even the most western examples from Wyoming have the rostral set well back between the internasals. The Wyoming series exhibits the following variations: ventral scutes, 213-223; labials, 8-9/11-13; scale rows, 30-31 (30 only once); dorsal saddles, 58-72. The scale rows of eastern examples are usually 28 to 30 in number, in contrast to the higher indication for those from Wyoming. The coloration is about the same throughout the range of *sayi*, but a tendency toward a decrease in the size and number of the dark markings on the ventral scutes is observed in western specimens. In this connection, an example from Sheridan county, Nebraska, is entirely devoid of dark ventral markings.

Two adult females from Butler county, Kansas, were found to contain large eggs in the oviducts on June 26, 1931, one having five eggs and the other double that number. A specimen collected in Chase county, Kansas, on May 12, 1933, had a young black-eared jack rabbit (*Lepus californicus melanotus*) in its stomach.

ILLINOIS.

HENRY: 4 mi. S. Cleveland (Burt, June 8, 1931).

IOWA.

JASPER: 1 mi. E. Colfax (Burt, June 8, 1931).

PAGE: 2 mi. W. Clarinda (Burt, June 8, 1931).

KANSAS.

BARBER: Deerhead (Smith, September 7, 1933); 2 mi. W. Medicine Lodge (Rogers, October 16, 1933); Sharon (Smith, September 7, 1933).

BUTLER: Augusta (Burt, June 26, 1931); 1 mi. S. W. Cassoday (Burt, May 12, 1933); 3 mi. S. E. Douglas (Burt, June 26, 1931).

CHASE: Bazaar (Hoyle, May 12, 1933).
COWLEY: 1 mi. S. Akron (Hoyle, August 27, 1933); 1 mi. E. Arkansas City (Burt, May 6, 1933); 2 mi. N. E. Burden (Harold Lyon, July 17, 1933); 6 mi. E. Cambridge (Burt, June 3, 1933); 1 mi. N. Hooser (Hoyle, August 17, 1933); 10 mi. E. Winfield (Anderson, May 8, 1933); 8 mi. N. Winfield (Burt, June, 1931).
DICKINSON: 3 mi. N. Elmo (Burt, May 15, 1933); 2 mi. S. W. Hope (Hoyle, May 14, 1933).
ELLSWORTH: County line W. Brookville (Smith, 1932).
GEARY: 4 mi. S. Junction City (Burt, June, 1931).
GREENWOOD: 2 mi. S. E. Climax (Burt, June 3, 1933); 8 mi. S. Tonovay (Burt, June 3, 1933).
HARPER: Harper (Tihen, August, 1933).
JEFFERSON: 1 mi. N. Rock Creek (Burt, June 3, 1933); 4 mi. S. Valley Falls (Burt, June 3, 1933).
MARSHALL: 2 mi. W. Blue Rapids (Burt, June 23, 1931); 3 mi. N. Marysville (Burt, June, 1931).
MORRIS: 3 mi. E. Delavan (Hoyle, May 14, 1933).
OSAGE: 3 mi. N. Osage City (Burt, May 14, 1933).
RILEY: 5 mi. W. Cleburne (Burt, June 25, 1931).
SALINE: 4 mi. S. E. Mentor (Hoyle, May 14, 1933).
SUMNER: Argonia (Burt, October 14, 1933).
WABAUNSEE: 5 mi. W. Maplehill (Hoyle, May 13, 1933).
WASHINGTON: 1 mi. S. Greenleaf (Burt, June 23, 1931).

NEBRASKA.

CHERRY: Simeon (Burt, August 18, 1931).
DODGE: 4 mi. S. E. Schribner (Burt, June 10, 1931).
GAGE: Blue Springs (Burt, August 30, 1932); 1 mi. S. W. Cortland (Burt, August 9, 1933); 7 mi. E. Odell (Burt, May 15, 1933).
JEFFERSON: 6 mi. E. Reynolds (Hoyle, May 15, 1933).
KNOX: 1 mi. W. Niobrara (Burt, August 11, 1933).
LANCASTER: Lincoln (Univ. Nebr. Mus., June 11, 1920).
MORRILL: 5 mi. S. W. Bonner (Burt, August 17, 1931).
SHERIDAN: 4 mi. E. Bingham (Burt, August 17, 1931).

OKLAHOMA.

GARFIELD: 5 mi. N. Enid (Hoyle, June 9, 1933).

SOUTH DAKOTA.

MELLETTE: 9 mi. E. Cedarbutte (Burt, August 10, 1931).
TRIPP: 5 mi. S. E. Witten (Burt, August 10, 1931).

WYOMING.

BIGHORN: 3 mi. N. Basin (Burt, August 16, 1931).
CONVERSE: 6 mi. W. Careyhurst (Burt, August 17, 1931); 2 mi. W. Glenrock (Burt, August 17, 1931).
FREMONT: 8 mi. N. W. Diversion Dam (Burt, August 13, 1931).
JOHNSON: 16 mi. S. Buffalo (Burt, August 16, 1931).

Lampropeltis calligaster (Harlan)

A note on the mimicry of the young of this species to like-sized prairie rattlesnakes (*Sistrurus catenatus catenatus*) is given above under *Elaphe læta*.

ARKANSAS.

POPE: 5 mi. N. W. London (Burt, June 28, 1931).

KANSAS.

BUTLER: 4 mi. W. Leon (Smith, September 9, 1933).
CHASE: 2 mi. W. Cottonwood Falls (Smith, September 1, 1933).
CHAUTAUQUA: 1 mi. E. Cedarvale (Hoyle, May 6, 1933).
COWLEY: 4 mi. S. E. Hooser (Burt, May 6, 1933).

ELK: 2 mi. N. W. Grenola (Hoyle, September 8, 1933).
HARPER: 1 mi. N. Harper (Tihen, August 31, 1933).
MONTGOMERY: Independence (Robb, July 6, 1933).
MORRIS: 6 mi. E. Council Grove (Burt, May 14, 1933).
POTTAWATOMIE: Onaga (Smith, April 8, 1933).
SEDGWICK: Clearwater (Whitney, October 10, 1933); 3 mi. N. W. Clearwater (Peterson, April, 1933).
WABAUNSEE: 5 mi. W. Maplehill (Hoyle, May 13, 1933).

MISSOURI.
PHELPS: 6 mi. W. Rolla (Burt, August 31, 1933).

OKLAHOMA.
KAY: 6 mi. N. E. Newkirk (Hoyle, April 29, 1933).

Lampropeltis getulus holbrooki Stejneger

This snake inhabits both sparsely wooded tracts and the open prairie, where it is especially apt to occur about rock ledges.

KANSAS.
CLAY: Clay Center (Smith, April 9, 1933).
COWLEY: 10 mi. E. Winfield (Strother, May 8, 1933); 9 mi. N. E. Winfield (Burt, May 7, 1933).
WABAUNSEE: 5 mi. W. Maplehill (Hoyle, May 13, 1933).

OKLAHOMA.
KAY: 6 mi. N. E. Newkirk (Burt, April 29, 1933).
ROGERS: 6 mi. W. Claremore (Burt, April 23, 1933).

Lampropeltis triangulum gentilis (Baird and Girard)

This beautiful king snake often occurs in the vicinity of the limestone ledges of the treeless prairie in central Kansas, where it is in much the same habitat as *Crotaphytus collaris*.

KANSAS.
CLAY: Clay Center (Smith, April 9, 1933).
CLOUD: Miltonvale (Smith, April 8, 1933).

NEBRASKA.
LANCASTER: Lincoln (Wolcott, May, 1897).

OKLAHOMA.
BECKHAM: 2 mi. E. Sayre (Hoyle, June 10, 1933).

Lampropeltis triangulum syspila (Cope)

In Kansas, this subspecies appears in the same general habitat as *gentilis*. An example was obtained under a flat limestone rock in a prairie ledge 7 miles north of Alma, Waubaunsee county, on May 13, 1933.

Sonora semiannulata Baird and Girard

This snake appears to inhabit relatively dry areas in the prairie, as compared with such reptiles as *Eumeces obsoletus* and *Tantilla gracilis gracilis*, although it may occur with these forms in marginal zones near woods where a moderate amount of moisture is available. *Sonora* is often abundant in local areas in prairie ledges in the spring, but it seems very difficult to secure specimens at other times of the year.

An example from Cowley county, Kansas, is abnormal in that the loreal is fused to the prefrontal on each side.

KANSAS.

COWLEY: 7 mi. N. E. Winfield (Hoyle, May 21, 1933).
WILSON: 4 mi. W. Neodesha (Burt, April 22, 1933).

OKLAHOMA.

LOGAN: 2 mi. N. Mulhall (Burt, April 15, 1932).
NOBLE: 3 mi. N. Orlando (Burt, April 15, 1932).
OSAGE: 2 mi. S. E. Avant (Hoyle, April 23, 1933); 4 mi. W. Pawhuska (Burt, April 8, 1933).
ROGERS: 6 mi. W. Claremore (Burt, April 23, 1933).

Natrix grahamii (Baird and Girard)

This watersnake may be taken, now and then, under rocks at the side of riffles in the streams of eastern Kansas, where it is usually less abundant than *sipedon* of the same general habitat.

KANSAS.

OSAGE: 2 mi. S. Barclay (Burt, June 3, 1933).

NEBRASKA.

LANCASTER: 4 mi. E. Havelock (Powell, July, 1931); Lincoln (Univ. Nebr. Mus., July 14, 1930).

Natrix rhombifera (Hallowell)

One of these snakes was found at the side of a shallow roadside ditch near a garden and above a culvert in Labette county, Kansas, on April 22, 1933. When discovered it had only the top of its head and its eyes above the surface of the water. The head was seized and the snake attempted to withdraw into a shallow tunnel in the earth. Failing in this it made an effort to disconcert its captor by the use of its nauseating odoriferous secretion as it wound about his arm.

KANSAS.

COWLEY: 7 mi. N. E. Winfield (Anderson, April 22, 1933).
GREENWOOD: 6 mi. S. Tonovay on Fall river (Burt, June 3, 1933).
LABETTE: Montana (Burt, April 22, 1933).

Natrix sipedon sipedon (Linnæus)

When perched upon roots, brush or grapevines above the water of small streams, these snakes are afforded a high degree of protective coloration, and such individuals are often discovered only when they rush into the water after their would-be observer makes too close an approach.

Rana pipiens often falls victim to this snake, and we have observed this *Natrix* with these frogs in their mouths on several different occasions. When first pierced by the sharp recurved teeth of the snake, *Rana* often gives forth a piteous cry, which is strikingly suggestive of the high pitched shriek of a human infant in terror and pain.

ARKANSAS.

MADISON: 3 mi. S. Delaney (Burt, June 28, 1931).
PERRY: 6 mi. W. Casa (Burt, June 29, 1931).

INDIANA.

WARREN: 2 mi. S. Carbondale on Fall creek (Burt, June 7, 1933).

IOWA.

MONROE: 2 mi. W. Albia (Burt, June 8, 1931).

KANSAS.

CHASE: 5 mi. N. Matfield Green (Smith, September 9, 1933).
COWLEY: 5 mi. N. E. New Salem (Hoyle, July 18, 1933).
ELK: 2 mi. N. W. Grenola (Hoyle, August 22, 1933).
ELLSWORTH: County line W. Brookville (Smith, 1932).
GREENWOOD: 6 mi. S. Tonovay (Burt, June 3, 1933).
MARION: 5 mi. S. Marion (Burt, May 15, 1933).
MARSHALL: 2 mi. S. Blue Rapids (Nelson, August 1, 1933).
OSAGE: 4 mi. N. Lyndon on Dragoon creek (Burt, June 3, 1933).
OTTAWA: Ada (Smith, April 8, 1933).
SALINE: 4 mi. W. Gypsum (Hoyle, May 14, 1933).
SHAWNEE: Wakarusa river (Dunkle, May 16, 1933).

NEBRASKA.

CHERRY: 8 mi. S. E. Valentine (McGrew, July, 1933).

Natrix sipedon transversa (Hallowell)

The alternation of the dorsal and lateral dark spots of this form is often irregular anteriorly, and the scale rows may be 23, as in the case of an example from Beckham county, Oklahoma. On the other hand, *Natrix sipedon sipedon* may have 25 scale rows (Cowley county, Kansas).

ARKANSAS.

MADISON: 3 mi. S. Delaney (Burt, June 28, 1931).

KANSAS.

CLARK: 4 mi. W. Englewood (Smith, July 23, 1933).
COMANCHE: 16 mi. E. Ashland on Bluff creek (Smith, July 24, 1933).
KINGMAN: Kingman (Tihen, August 20, 1933).

OKLAHOMA.

BECKHAM: 4 mi. S. W. Sayre (Hoyle, June 10, 1933).

Storeria dekayi (Holbrook)

This snake apparently occurs only where moisture is fairly abundant, as in deeper woods.

KANSAS.

CHEROKEE: 3 mi. N. Baxter Springs near Spring river (Taylor, April 4, 1931).
SEDGWICK: 3 mi. S. Clearwater (Schreck, January, 1933).

Storeria occipito-maculata (Storer)

This species was revealed under a stone in a deeply wooded area near Spring river on April 4, 1931, at a point about 2 miles north of Baxter Springs, Cherokee county, Kansas (Smith).

Potamophis striatulus (Linnæus)

This little brown snake was taken under a rock in a prairie ledge near sparse woods 7 miles west of Bartlesville, Osage county, Oklahoma, on April 3, 1933.

Thamnophis lineatus (Hallowell)

The odoriferous secretion of this dwarf garter-snake resembles that of *parietalis,* which may occur in the same general habitat.

KANSAS.

CLAY: Clay Center (Smith, April 9, 1933).
DICKINSON: 4 mi. N. W. Herington (Hoyle, May 14, 1933).
LINCOLN: 10 mi. S. W. Lincoln (Burt, May 14, 1933).

MONTGOMERY: 5 mi. N. E. Elk City (Burt, April 22, 1933).
POTTAWATOMIE: Wheaton (Smith, April 9, 1933).
SHAWNEE: Berryton (Dunkle, May 14, 1933); 3 mi. W. Topeka (Hoyle, May 13, 1933).
WABAUNSEE: 7 mi. N. Alma (Burt, May 13, 1933); 3 mi. S. E. Wabaunsee (Hoyle, May 13, 1933).

NEBRASKA.

LANCASTER: Lincoln (Keech, October, 1933).

OKLAHOMA.

KAY: 6 mi. S. E. Chilocco (Burt, April 29, 1933); 6 mi. N. E. Newkirk (Hoyle, April 29, 1933).

Thamnophis ordinoides vagrans (Baird and Girard)

Wanderer garter-snakes are apparently the most common form of *Thamnophis* in Wyoming and the present records indicate that the subspecies has a very wide distribution in this state, where it occurs near streams and ponds.

WYOMING.

CONVERSE: 7 mi. N. W. Douglas (Burt, August 16, 1931).
NIOBRARA: 2½ mi. N. Hat Creek Store on Hat creek, near bridge (Burt, August 12, 1931).
PARK: N. Fork Shoshone river in Shoshone National Forest, just E. entrance to Yellowstone National Park (Burt, August 15, 1931); 6 mi. E. Cody (Burt, August 15, 1931).

Thamnophis radix radix (Baird and Girard)

One of these garter snakes was discovered with a large frog (*Rana pipiens*) in its mouth in Rock county, Nebraska, but when disturbed, the snake dropped the crying frog and wriggled into a hole in a hard earthen bank, where it was safe. Meanwhile, the wounded frog dived into a nearby pool of water, fleeing from the scene of its near-disaster, and escaping from both the snake and a would-be collector.

KANSAS.

COMANCHE: 3 mi. S. E. Arrington (Smith, September 5, 1933).
COWLEY: 8 mi. N. Winfield (Hadley, May 8, 1932).
DICKINSON: 4 mi. N. W. Herington (Burt, May 14, 1933).
GREENWOOD: 3 mi. S. Madison (Burt, June 3, 1933).
WALLACE: Rhino Hill (Elias, May 29, 1933).

MISSOURI.

LINN: 4 mi. W. Laclede (Burt, June 4, 1933).

NEBRASKA.

CHERRY: Valentine (Burt, August 18, 1931).
MORRILL: 8 mi. E. Bayard (Burt, August 17, 1931).
PIERCE: 1 mi. N. Hadar (Burt, August 9, 1931).
ROCK: 2 mi. E. Bassett (Burt, August 19, 1931).
SCOTTS BLUFF: 3 mi. N. W. Morrill (Burt, August 17, 1931).
SHERIDAN: 3 mi. E. Lakeside (Burt, August 17, 1931); 2 mi. W. Ellsworth (Burt, August 17, 1931).

SOUTH DAKOTA.

JACKSON: Belvidere (Burt, August 10, 1931).
PENNINGTON: 2 mi. S. E. Caputa (Burt, August 11, 1931).

Thamnophis sauritus proxiums (Say)

A female ribbon snake, which was collected in Greer county, Oklahoma, on June 10, 1933, had six eggs in the right oviduct and three in the left.

ARKANSAS.

DREW: 2 mi. S. Winchester (Burt, June 29, 1931).

KANSAS.

HARPER: 4 mi. N. and 8 mi. E. Harper (Tihen, August 23, 1933).

MISSOURI.

LINN: 4 mi. W. Laclede (Burt, June 4, 1933).

OKLAHOMA.

BECKHAM: 4 mi. S. W. Sayre (Hoyle, June 10, 1933).
COMANCHE: Wichita Mts. (K. S. C. Mus., July 13, 1931).
GREER: 4 mi. S. E. Mangum (Hoyle, June 10, 1933).

Thamnophis sirtalis parietalis (Say)

The light stripe of this form lies "anteriorly" on the second and third rows, *if* the count is made an inch or so back from the head. An example found in the road in Cowley county, Kansas, on a windy day (May 6, 1933) side-winded across the highway and flattened its body like the hog-nosed snakes, displaying much bad temper as it was approached. Most individuals are much more gentle, however, even at the time of capture.

In a hay field above a small sandhill stream near Wood Lake, Nebraska, one of these red-sided garter snakes was found with a frog (*Rana pipiens*) in its stomach; and a second example was obtained in a seine at a stagnant pool, which had much algæ at the bottom, in Custer county, South Dakota. Here, the snake was associated with various stages of the leopard frog (*Rana pipiens*) and with many larvæ of the tiger salamander (*Ambystoma tigrinum*).

KANSAS.

BUTLER: 5 mi. S. Augusta (Burt, May 16, 1933).
CLAY: Clay Center (Smith, April 9, 1933).
COWLEY: 1 mi. E. Cameron (Hoyle, May 6, 1933); 8 mi. N. E. Winfield (Hoyle, April 21, 1933).
DICKINSON: 4 mi. N. W. Herington (Hoyle, May 14, 1933).
ELK: 3 mi. W. Grenola (Harold Lyon, May 30, 1933).
LABETTE: Labette Ozarks near Mortimer (Burt, April 22, 1933).
MORRIS: 9 mi. S. W. Council Grove (Burt, May 12, 1933).
POTTAWATOMIE: Onaga (Smith, April 8, 1933); 1 mi. N. Westmoreland (Smith, April 9, 1933).
SHAWNEE: Wakarusa river (Dunkle, May 16, 1933).

MISSOURI.

BUCHANAN: 2 mi. S. Rushville (Burt, June 3, 1933).

NEBRASKA.

CHERRY: 7 mi. N. W. Wood Lake (Burt, August 18, 1931).
COLFAX: 5 mi. S. E. Clarkson (Burt, August 9, 1931).
GAGE: 2 mi. W. Odell (Hoyle, May 15, 1933).
GRANT: 3 mi. W. Duluth (Burt, August 18, 1931).
SCOTTS BLUFF: 3 mi. S. E. Henry (Burt, August 17, 1931).
WAYNE: 7 mi. N. Pilger (Burt, August 9, 1931).

SOUTH DAKOTA.

CUSTER: 4 mi. E. Pringle (Burt, August 11, 1931).

Tantilla gracilis gracilis Baird and Girard

While a specimen of the leopard frog (*Rana pipiens*) was being dissected in the laboratory, an examination of its stomach contents revealed a partially digested snake of this subspecies.

KANSAS.

CHASE: 2 mi. W. Cottonwood Falls (Smith, September 1, 1933); 5 mi. N. Strong City (Burt, May 12, 1933).
CHAUTAUQUA: 3 mi. W. Peru (Hoyle, April 3, 1933).
COWLEY: 1 mi. N. E. Cambridge (Hoyle, April 22, 1933); 1 mi. N. Maple City (Burt, May 6, 1933).
POTTAWATOMIE: 2 mi. N. E. Rocky Ford power plant (Hoyle, May 15, 1933).
WILSON: 4 mi. W. Neodesha (Gerboth, April 22, 1933).

OKLAHOMA.

CRAIG: 4 mi. S. W. Whiteoak (Burt, April 23, 1933).
KAY: 6 mi. S. E. Chilocco (Hoyle, April 29, 1933); 6 mi. N. E. Newkirk (Burt, April 29, 1933).
OSAGE: 2 mi. S. E. Avant (Hoyle, April 23, 1933); 7 mi. W. Bartlesville (Burt, April 3, 1933); 4 mi. W. Pawhuska (Burt, April 3, 1933).
ROGERS: 6 mi. W. Claremore (Hoyle, April 23, 1933).

Tantilla gracilis nigriceps Kennicott

This form was taken at Hays, Ellis county, Kansas, by Leo Brown in April, 1932.

Agkistrodon mokasen Beauvois

Copperhead snakes are often active on warm evenings just at sunset. A young specimen that measured 317 mm. in total length was kept in the laboratory without food for four months (October to February). An adult killed near Winfield was left lying near a rock quarry on August 1. Shortly afterward, the snake (which was cut into two pieces through the center) was handled by a little girl about five years of age, who received a definite bite from the head end. The victim was rushed to a doctor, but serious symptoms did not develop, and the patient was discharged after preliminary treatment for snake bite and continued observation.

KANSAS.

CHAUTAUQUA: 4¾ mi. S. E. Cedarvale at Camp Ta-la-hi (Hoyle, July 26, 1932).
CHEROKEE: 2 mi. N. Baxter Springs (Smith, March 25, 1932).
COWLEY: 10 mi. E. Winfield (Hoyle, August 1, 1933).
ELK: 3 mi. N. W. Grenola (Hoyle, August 23, 1933).

Sistrurus catenatus catenatus (Rafinesque)

One of these rattlesnakes was chased into a natural hole in the side of a rounded rock, and thereby it completely concealed itself. The rock was only about ten inches in diameter and the snake did not come from its shelter until the stone had been rolled over a number of times.

KANSAS.

COWLEY: 6 mi. N. Winfield (Hadley, May 8, 1932); 3 mi. N. E. Winfield (Hoyle, August 1, 1933).

Crotalus confluentus confluentus Say

Through the courtesy of Mr. L. M. Klauber, we are able to include a number of Kansas records in the list below from specimens that he has examined. An example from Fremont county, Wyoming, shows the following characters:

ventrals, 177; subcaudals 25; rattles, 10; scale rows, 25-25-19; labials, 14/15; dorsal saddles, 41 on the body and 9 on the tail, 50 in all.

KANSAS.
- BARBER: 5 mi. S. Sun City (Smith, September 3, 1933).
- CHEYENNE: (Gloyd).
- COMANCHE: Arrington (Smith, September 5, 1933).
- ELLIS: Fort Hays (Allen).
- HODGEMAN: Jetmore (October 9, 1929).
- NESS: (Gloyd, May 1, 1927).
- THOMAS: Gem (Perkins, December 18, 1931).
- TREGO: Castle Rock (Taylor, June 20, 1912).

SOUTH DAKOTA.
- JACKSON: 10 mi. W. Kadoka (Burt, August 11, 1931).

WYOMING.
- FREMONT: 8 mi. E. Moneta (Burt, August 13, 1931).

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Studies on the Retinal Pigment of the Embryo Chick*

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(PLATE III)

INTRODUCTION

The origin and the early development of the retinal pigment of the embryo chick constitutes one of the problematical phases of animal histogenesis.

The conflict of data concerning retinal pigment led to this investigation of the origin of pigment: 1, to determine if granules arise independently in the cytoplasm; 2, to establish a definite time for their first appearance; 3, to see what changes in color, shape, and size take place in their development.

SURVEY OF THE LITERATURE

Ucke (*9*) refers to the pigment granules as commencing to develop in the retina about the middle of the fourth day (96 hours) of incubation.

Weysse and Burgess (*10*) say: "Pigment commences to form as early as three and two-thirds days (88 hours) of incubation."

Smith (*8*) says: "The first signs of pigmentation are found by vital staining at the stage of forty-two hours incubation. A few small colorless and small gray granules are seen in the cytoplasm of the cell. These granules gradually increase in size, number, and depth of color until the cell becomes full of rod-shaped granules at seventeen days." Smith further describes two separate steps in the formation of pigment: first, the formation of a colorless chromogen, followed by, second, the formation of color in the chromogen. At sixty hours the first signs of color in the chromogen are noted, but they do not begin to reach their maximum size and depth of color until after sixty-six hours.

Miescher (*6*) gives three to four days (seventy-two to ninety-six hours) as time of the first appearance of pigment.

Patten (*7*) states that pigment arises during the fourth day (ninety-six hours) after incubation.

Lillie (*4*) and McEwen (*5*) affirm this statement.

It has been generally recognized by other investigators that pigment arises about eighty-eight to ninety-six hours after incubation.

Smith is the only one who describes pigment appearing earlier than seventy-two hours. The many investigators have either overlooked the research by Smith or there is still some uncertainty concerning the exact time of the appearance of pigment. It may also be a matter of the technique employed.

MATERIALS AND METHODS

For this investigation, eggs from a Buff Orpington stock of chickens were used. The eggs were gathered in the evening and placed in the incubator within twenty-four hours. During the fall and winter months, they were kept between 12° and 18° C. before being put into the incubator. During the late spring and early summer months, the eggs were kept as near that temperature as the weather would permit. Allowing one hour for warming, the eggs were incubated from forty-eight to ninety-six hours.

*Condensed from a dissertation for Master of Science degree at University of Wichita.

The eggs were opened at room temperature and fixative was immediately poured over the embryos. After about five minutes the embryos were removed from the yolk, and placed in stender dishes containing fixative to the amount of ten times the volume of the chicks. The following fixatives were used:

1. Bouin (37° C.), 6 hours.
2. 10 per cent formalin, 48 hours.
3. Dietrich's fluid, 48 hours.
4. Acetic formalin, 48 hours.
   97 c. c. of 10 per cent formalin.
   3 c. c. of glacial acetic acid.
5. Flemming's, 24 hours.
6. Zenker's, 12 hours.
7. Zenker's without acetic acid, 12 hours.
8. Alcohol formalin, 48 hours.
   90 c. c. of 70 per cent alcohol.
   7 c. c. of 10 per cent formalin.

From Bouin's, the embryos were dehydrated in the following grades of alcohol for 1.5 to 2 hours: 35 per cent, 50 per cent, 70 per cent, 85 per cent, 95 per cent, and absolute. They were then placed in one-half absolute alcohol and one-half chloroform for one hour, cleared in chloroform for one hour, infiltrated with paraffin for 1½ hours and embedded in paraffin.

From 10 per cent formalin, alcohol formalin, acetic formalin, and Dietrich's fluid, the embryos were placed directly in 70 per cent alcohol, and the procedure followed as with the Bouin's solution.

Embryos fixed with Zenker's and with Zenker's without acetic acid were washed twelve hours in running water, then transferred to 35 per cent alcohol and 50 per cent alcohol for twenty minutes each, and into 70 per cent alcohol. Sufficient iodine solution to give the alcohol a port-wine color was added to remove the corrosive sublimate from the tissue. After twenty-four hours of this treatment, the embryos were transferred to fresh 70 per cent alcohol for one hour and dehydrated as before.

All of the embryos were sectioned at six to eight microns, mounted in series, stained with Delafield's hematoxylin and counterstained with dilute eosin in 95 per cent alcohol. The light stains in which there was very little eosin and just enough hematoxylin to stain the nuclear parts were the best.

For the purpose of counting somites as a check on the age of the chicks, embryos incubated along with those to be sectioned were stained *in toto* with Delafield's hematoxylin. Xylene was substituted for chloroform in clearing, and whole mounts in balsam were made.

Light filters of blue, green, red, violet and orange were used for determining the density of the pigment.

The sections were examined under a binocular microscope equipped with a flourite oil immersion (1.8) objective with 10x oculars.

OBSERVATIONS

Description of the Pigment Layer. The pigment layer of the retina is a single layer of irregularly prismatic cells which are mostly hexagonal. It rests on a basement membrane, the lamina basalis (*1*). The nuclei of these cells are, for the most part, in the resting stage. Here and there a few mitotic figures can be observed. The nuclear membrane appears, for the most part,

intact. Occasionally the chromosomes of a cell undergoing mitosis would assume odd shapes and appear to be pushing out the nuclear membrane.

The pigment layer is continuous with the visual layer at the lens and at the choroid fissure.

In the early stages of the chick (sixty-two hours or thirty-two somites), all the cells of the entire pigment layer are about equal in size. As the chick grows older, the cells in the fundus of the optic cup tend to decrease in size. The cells in that region of the pigment layer of the ninety-hour chick (Fig. 13) measured one-half that from the corresponding region of the sixty-two hour chick (Figs. 3 and 13). Towards the lens the cells are more nearly the same size (Figs. 6 and 14).

Figures 6, 8, 10 and 13 show this gradual decrease in size through the sixty-two hour, the seventy-hour, the eighty-hour, and the ninety-hour chick in the region of the fundus. There is a slight variation in the eighty-hour chick. This is accounted for by the fact that the section from which the drawing was made was cut sagittally while the others were cut in cross sections. Figs. 7, 9, 11 and 14 show the increase in size of the cells in the region near the lens in the above ages of chicks.

"Pigment Rods" or "Pigment Granules." Throughout the literature, the coloring matter of the pigment layor is described as "granules." According to Webster's unabridged dictionary, a granule is defined as "the smallest, minute, sensible component part of an aggregation or mass conceived of as being without extension but retaining the other properties of matter such as inertia and attraction." A rod is defined as "An animal or vegetable structure having an elongated slender form." Cowdry (*1*) states that the pigment body of the pigment layer from different animals has a characteristic shape for that animal. The pigment body in the chick has an elongated slender form and should be considered as a "rod." (Figs. 4 and 5.) Owing to this characteristic rod-shape, the common expression "pigment granule" is erroneous. In undifferentiated material these pigment rods clump together and give the appearance usually described as granular.

The Nature of the Pigment Rod. The pigment rod is made up of two elements: 1, a brown-colored fuscin—a peculiar kind of melanin, and 2, an albuminous crystalline ground substance. It develops as an oxidation product by means of an oxidation-fermentation reaction. The seat of the reaction is the protoplasm of the pigment-forming cells. It is only evident in the early embryonic stages. After the cells are completely filled with pigment, the reaction disappears either completely or is only present to a slight degree (*6*).

Various color filters were used for studying the depth of color, and the violet light was found to cut out most of the cell structure and intensified the pigment rods so that they appeared very dark against a faintly visible background. Since violet light intensifies shades of yellow varying to brown, it is reasonable to assume that it is brown pigment which was observed in the early stages of its first appearance and not some other rod-shaped cell inclusion.

Pigment rods always occurred in the cytoplasm. There was no pigment observed in the nucleus. In some cells undergoing mitosis, the broken-up chromosomes appeared, under ordinary light, almost the same as pigment rods. However, when the violet light filter was used, the chromosomes faded out, as did the rest of the cellular elements, leaving the pigment rods clearly visible.

Miescher (*6*) states: "Mitochondria, found at the base of the cells, is the antecedent to pigment granules." Hooker (*2*) and Smith (*8*) agree that pigment arises and develops in the cytoplasm, and is not to be correlated with any definite precursor.

With the type of stain used, it was impossible to observe any mitochondria. Mitochondria are soluble in acetic acid (*8*). Pigment is not soluble in acetic acid because embryos fixed with reagents containing acetic acid showed the same amount of pigment as did those fixed in reagents which did not contain acetic acid. Unless the mitochondria undergo a change in transforming to pigment, the mitochondria should not be considered a precursor of pigment (*6*).

COMPARATIVE APPEARANCE OF PIGMENT IN SEVERAL AGES OF CHICK. There is a gradual increase in the number of pigment rods with the age of the chick.

The pigment layer of the week-old chick is very heavily packed with pigment rods, especially in the fundus of the optic cup (Fig. 12). In the region nearest the lens, the rods scatter out somewhat so that it is possible to measure isolated pigment rods. At their maximum they measure 1.6×0.5 microns. The color is very dark brown—almost black.

In the ninety-hour chick, the cells of the pigment layer are well filled with pigment rods. The cells in the fundus of the optic cup are about one-half the size of those of the same region in the sixty-two-hour chick. (Figs. 3 and 13.) The pigment rods are located near the chorioid layer away from the visual layer. (Figs. 2 and 13.) They appear in aggregations of pigment rods with a few scattered rods here and there in the fundus region, and are scattered throughout the entire cell in the region towards the lens. (Figs. 13 and 14.)

A few cells of the pigment layer seem to be pushing out the cell membrane. This may be the beginning of what Lewis (*3*) describes as pigment buds and wandering pigmented cells in the chorioid layer.

The pigment layer of the eighty- and the seventy-hour chick appears very similar to that of the ninety-hour chick except that there is a corresponding decrease in the number of pigment rods. (Figs. 8, 9, 10 and 11.) The cells of the pigment layer of the seventy-hour chick are larger than those of the eighty-hour chick. The cells of the pigment layer of the eighty-hour chick are larger than those of the ninety-hour chick. (7 microns.)

The cells of the pigment layer of the sixty-two hour chick are large (14 microns) and here and there a few scattered rods appear on the side away from the visual layer. They occur in the cytoplasm between the nucleus and the cell membrane. They vary in size from small dots of pigment to rods of maximum size and color. This is determined by measurement and by the use of the violet light filter. The pigment rods do not occur in all the cells, but in occasional cells located in the fundus of the optic cup. There are from one to four large pigment rods in each cell where pigment is observed. (Fig. 3.)

Smith describes chromogens as gradually increasing in size and depth of color until sixty-six hours, and that they do not begin to attain their maximum size and depth of color until this time. By measurement it was found that the longest pigment rods of the sixty-two-hour chick (thirty-two somites) measured the same as the longest of those found in the week-old chick. Smith (*8*) does not give a somite count nor the time of the year that his experiment was performed. It is possible that his sixty-six-hour chick is the same age as the sixty-two-hour chick described here.

COMPARISON OF THE SIXTY-TWO-HOUR CHICK WITH VARIOUS FIXATIVES

The common histological and embryological fixatives that are used in the laboratory were used in this study.

Embryos incubated together for sixty-two and for sixty-four hours were removed and placed in various fixatives.

Embryos fixed in Bouin's, Flemming's, 10 per cent formalin, and acetic formalin did not show pigment at sixty-four hours (thirty-three somites).

Embryos fixed with alcohol formalin, Dietrich's fluid and Zenker's showed the pigment at sixty-four hours, but only those embryos fixed in Dietrich's and Zenker's with and without acetic acid showed the pigment at sixty-two hours.

Dietrich's fluid was found to be the best and was used for the majority of the chicks. It does not cause the pigment bodies to mat together. Embryos fixed with Dietrich's fluid did not crumble so easily and took a lighter stain which was more valuable in studying the pigment rods.

SUMMARY

1. Pigment appears as early as sixty-two hours (thirty-two somites) after incubation in the pigment layer of the eye of the chick as fully developed pigment rods of maximum size and depth of color.

2. The presence of pigment at this stage refutes the statements that pigment arises three to four days after incubation, as is stated in the most recent textbooks of embryology.

3. Aggregations of pigment rods which push the cell wall out may be the beginning of the chorioid pigment.

4. Pigment rods are cytoplasmic. There is no evidence of any rods appearing in the nucleus.

5. Dietrich's and Zenker's fixatives are the best for showing pigment as early as sixty-two hours.

6. Pigment rods have definite size and shape and should not be called "granules."

7. Pigment rods in maximum size measure 1.6 microns in length and 0.5 microns in width.

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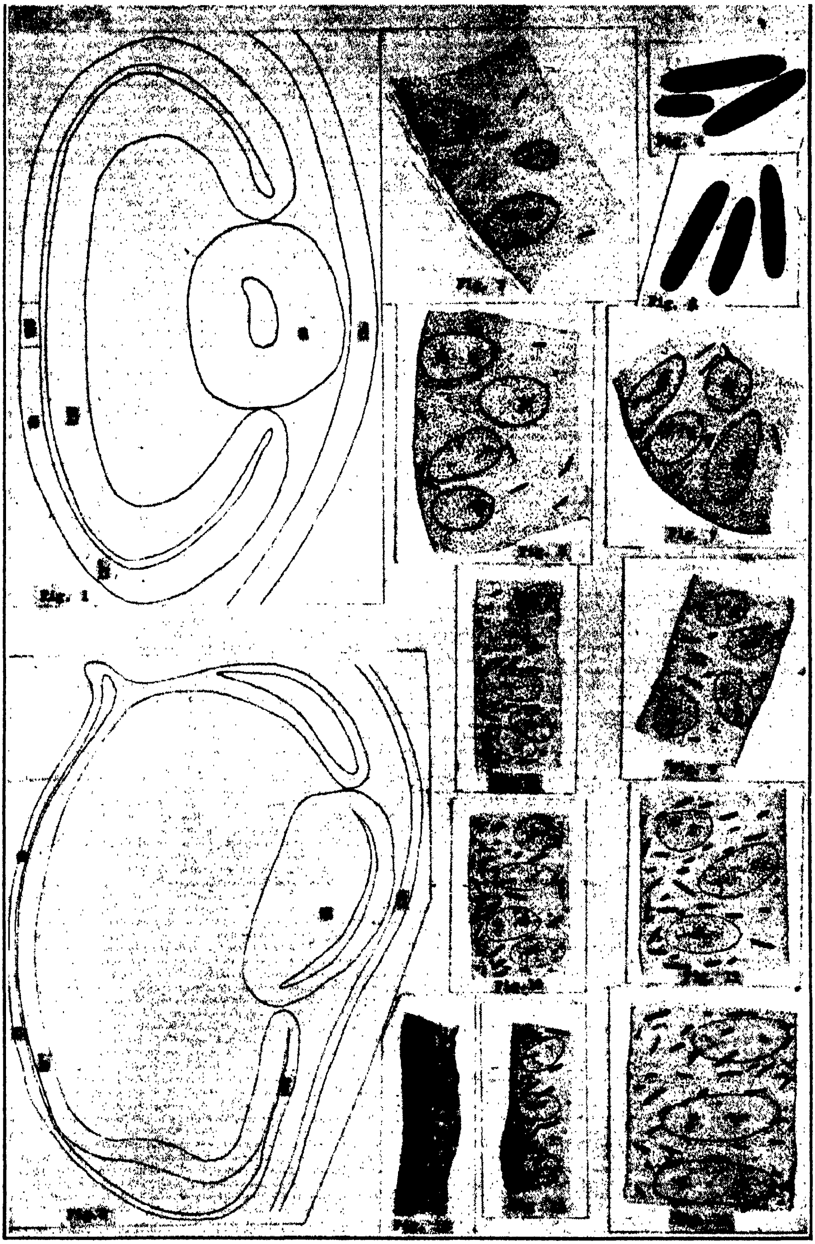
PLATE III

Fig. 1. Diagram of the eye of a sixty-four-hour chick.
- a. Lens.
- b. Visual layer.
- c. Pigment layer.
- d. Ectoderm.
- g. Region from which Figs. 3 and 6 were taken.
- h. Region from which Fig. 7 was taken.

Fig. 2. Diagram of the eye of a ninety-hour chick.
- e. Region from which Figs. 8, 10, 12 and 13 were taken.
- f. Region from which Figs. 9, 11 and 14 were taken.

Fig. 3. Sixty-two-hour chick, fundus region.
Fig. 4. Pigment rods from a sixty-two-hour chick.
Fig. 5. Pigment rods from a ninety-hour chick.
Fig. 6. Sixty-four-hour chick, fundus region.
Fig. 7. Sixty-four-hour chick, lens region.
Fig. 8. Seventy-hour chick, fundus region.
Fig. 9. Seventy-hour chick, lens region.
Fig. 10. Eighty-hour chick, fundus region.
Fig. 11. Eighty-hour chick, lens region.
Fig. 12. One-hundred-and-sixty-hour chick, fundus region.
Fig. 13. Ninety-hour chick, fundus region.
Fig. 14. Ninety-hour chick, lens region.
(Figs. 4 and 5 magnified 5,000 times, all others magnified 1,000 times.)

PLATE III



An Ecological Study of the Fishes of Mineral Lake, Kansas

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INTRODUCTION

Mineral Lake lies in the northeastern part of Cherokee county, about 20 miles southwest of Pittsburg, and 7 miles northwest of Columbus. The Missouri, Kansas and Texas railroad runs east and west along the south shore of the lake. A dam, twelve feet high, was constructed by this railroad at the southern part of the lake, giving to the lake its present size and area. Near

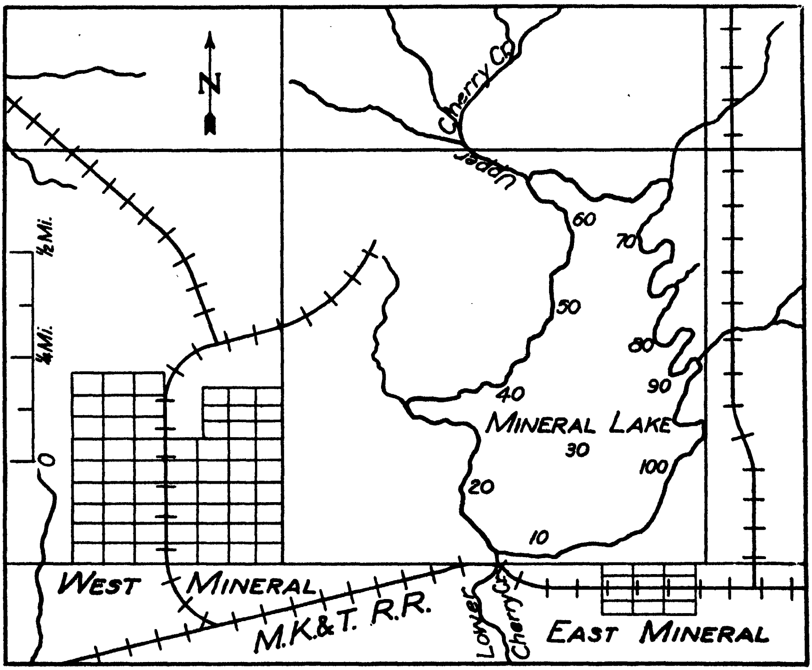

FIG. 1. Map of Mineral Lake and vicinity.

the south end of the west side of the lake is the town of West Mineral, with a population of about 700. Southeast of the lake is the small village of East Mineral, with a population of about 100.

The lake lies in a north-and-south direction, and its greatest length is approximately one mile. The maximum width is approximately one-half mile, and the lake has a total area of 156 acres. The average shore line is 3.9 miles. The greatest depth is 14 feet and the mean depth is about 4 feet. The form of the lake is somewhat irregular, especially on the east side. The north part of the lake is considerably narrower than the south half. (Fig. 1.)

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The total drainage of the lake is approximately 3,200 acres, or about 5 square miles. As there are no springs in this region, the amount of water in the lake is entirely dependent upon rainfall. Since the mean precipitation in this region is 45.12 inches, water lost through evaporation and overflow is continually being replenished.

The territory surrounding Mineral Lake consists mainly of residual prairie country. Most of the upland part of this region consists of undulating to gently rolling prairie, with an elevation of 900 feet at Mineral Lake. The stream bottoms and terraces are usually level. In general, this region consists of a broad plain, with broad, shallow, flat-bottomed valleys along the larger streams. Upper Cherry creek flows into the lake from the north and Lower Cherry creek is the outlet to the lake.

The climate of the Mineral Lake region is not typical of Kansas nor of any of the four states which practically meet at the southeastern corner of Cherokee county. Situated in the extreme southeast corner of the state, it has the greatest amount of rainfall and probably the longest growing season of any county in Kansas. The mean temperatures for the different seasons, 34.3° F. for winter, 77.2° F. for summer, indicate that the average winter is mild, and that the average summer is not excessively hot.

The records of precipitation show that the mean for over thirty years for the winter months is 5.97 inches, spring months, 13.65 inches, summer months, 13.45 inches, and fall months, 9.46 inches. The precipitation is fairly well distributed throughout the year, and over half of the total occurs in the spring and summer, during the growing season. The prevailing southwesterly winds sweep over the lake continuously, keeping the water well oxygenated at all times.

The ecological study of the fishes of Mineral Lake was carried on during the years 1926 to 1931, inclusive. It included (*a*) the collecting and listing of all the species of fishes found in this region, (*b*) the description of the exact habitats of all species collected, (*c*) the study of the combination of environmental factors which cause each different habitat to possess its own characteristic community of fishes, in order to attempt to interpret the fish fauna of this region from an ecological standpoint.

Observations were made regarding the spring, summer, and fall habitat of all the species. For the purpose of collecting, trammel nets, hoop nets, drag seines and fish traps were commonly used, and, at times, the hook and line. This method was supplemented, when there was opportunity, by the examination of fishes in live-bait boxes and in the catches of local fishermen. The fish, for identification, were kept alive if possible. Others were preserved in two to ten per cent of formalin. If the food of the fish was to be determined, the body cavity was opened to allow the preservative free and immediate access to the digestive tracts. All examinations were made as soon as possible. The stomach and intestines were removed, slit open, and the contents scraped out on a glass slide. The materials were examined carefully under a dissecting microscope, using the compound microscope when necessary. The different materials were segregated with needles and the percentage of the volume estimated (*1, 3, 4, 5*).

DESCRIPTION OF STATIONS

All stations from which observations were made, were selected because they represented typical aquatic habitats and ecological successions.

Station 10 is located on the south side of Mineral Lake approximately fifty feet from the shore. The bottom is of rock with a mixture of silt and some sand. The slope is gradual, and the depth ranges from six to nine feet. Vegetation, which consists of a few sedges and grasses, is sparse and does not extend to the water's edge. A few willows (*Salix*) and shrubs (*Ribes*) occur near the shore line.

Few minnows or other small fish were taken at this station. Apparently this is a poor feeding place and the smaller fish would be attacked by the black bass, which has been taken here. Marchantia and algæ are found on the surface of the rocks near the edge of the water. The principal fishes taken at this station were the black bass, common sunfish, yellow perch, and fresh-water drum.

Station 20 represents that stage in succession (*9, 10*) in which the pioneer hydrophytic plants, as algæ, duckweeds (*Lemna*), pondweeds (*Potamogeton*), are being replaced by an association of water chinquapins (*Nelumbo lutea*). Algæ, duckweeds, and pondweeds are found near the shore line and at places mixed with chinquapins. Schools of tadpoles and the young of the leopard frog are here in abundance. The bottom is of silt and ranges in depth from 1 to 5 feet. The slope is gradual. This station is characterized by an abundance of vegetation. The blunt-nosed minnow and golden shiner are common, as this is a typical habitat of the two species. Many young black bass and perch are found here. The vegetation afforded protection for them, and also an abundant supply of food. The principal species taken at this station were black bullheads, green perch, common sunfish, black bass, white and black crappie. Many large specimens of black bass, yellow perch, and black bullheads come at night to this station for the purpose of feeding upon the young fishes and other life found there.

Station 30 is situated near the center of the lake. The greatest depth of the lake is found at this station, approximately 14 feet. The bottom is of silt with a small quantity of sand. The depth of the silt varies from 12 to 18 inches. Due to the action of the wind, the deepest part of the lake is abundantly supplied with dissolved oxygen. For this reason such species as the large-mouthed black bass, small-mouthed black bass, yellow perch, fresh-water drum, and blue gill, thrive well in this deep-water habitat. These species were taken in the summer and fall at this station. In the spring the above-named species were taken in the more shallow parts of the lake, probably due to a greater food supply in shallow water, and also to their breeding habits.

Station 40 illustrates the bulrush-cattail stage characterized by such plants as the bulrush (*Scirpus*), the cattail (*Typha*), and arrowhead (*Sagittaria*), whose shoots extend well above the water. The trees are willows (*Salix*), ashes (*Fraxinus*), and maples (*Acer*). Kingfishers may be seen at this station at all times. The bottom is of silt, and the depth of the water from 3 to 6 feet. At places the slope is abrupt. The following were the principal species found here: red-mouthed buffalo, silvery minnow, black bullhead, blunt-nosed minnow, golden shiner, green perch, and white crappie. Other species were taken

here, especially toward evening, when the larger fish migrated from deeper water in search of food.

Station 50 is characterized by various grasses and sedges. Immediately north of this station is a large association of water smartweed (*Polygonum*), water crowfoot (*Ranunculus*), and water lilies (*Nymphaea*). This abundant vegetation affords protection and food for many species of fish. The bottom is of silt and the water is shallow, varying in depth from 1 to 2.5 feet. The blunt-nosed minnow and golden shiner were found here in abundance. The principal species, besides those named, were the black bullhead, white crappie, green sunfish, pumpkin seed, yellow perch, and orange-spotted sunfish.

Stations 60 and 70 are situated at the north end of the lake. The bottom is of silt, and the depth varies from 1 to 3 feet. The vegetation along the shore is dense and compact. Practically all plant associations may be found here. Duckweeds, pondweeds, water lilies, water crowfoot, bulrush, cattail, arrowhead, sedges, wild iris (*Iris*), button bush (*Cephalanthus*), willows, ashes and maples. The principal species taken were: black bullhead, common sunfish, golden shiner, blunt-nosed minnow, and silvery minnow.

Station 80 is situated on the northeast side of the lake. The bottom is mainly of silt with an intermixture of sand. The depth varies from 4 to 6 feet. Along the edge of the bank are various species of sedges, grasses, and flowering herbs. Beyond these are button bushes, willows, dogwoods, ashes and maples. The principal species taken here were the black bullhead, white crappie, blunt-nosed minnow, black crappie, bluegill, and yellow perch.

Station 90 has a shrub-bordered shore. Along the edge of the water are grasses and sedges. Button bushes, willows, and maples are farther from the shore. The dead trees furnish perches for kingfishers. The bottom is principally sand with a mixture of silt and some gravel. The depth varies from 3 to 6 feet. Fish find seclusion near and among the submerged bases of the plants. Black bass were frequently taken here. The principal species were, however, the golden shiner, straw-colored minnow, red-finned minnow, Storer's chub, orange-spotted sunfish, white crappie, and black bullhead.

Station 100 is near the southeastern part of the lake. The slope of the bottom is gradual. The bottom is of some silt and gravel. Along the shore the vegetation is abundant. Sedges, grasses, and water smartweed afforded protection for fish. The principal species taken here were the red horse, Storer's chub, golden shiner, straw-colored minnow, common sucker, bluegill, large-mouthed black bass, and fresh-water drum.

SYSTEMATIC LIST OF SPECIES

Each species is listed in the table according to the habitat in which it was collected. The habitats found in the lake are sufficiently diversified to provide suitable environments for species possessing widely different habitats. The bottom of the lake varies from soft black silt and decaying vegetation to that of silt and sand, sand, and rock. The depth varies from a few inches along the shore to 14 feet near the center of the lake. Thirty-two species are represented, distributed among 6 orders, 9 families, and 27 genera.

Observations were made regarding the spring, summer, and fall habitat of all the species. By means of the drag seine over selected areas near the collecting stations, 11 were found to have a preference for muddy bottom, 7 for

sandy bottom, and one for rocky bottom. Five species were found on both muddy and sandy bottom, 5 on both muddy and rocky bottom, 8 on both sandy and rocky bottom, and 5 were found over all bottoms. Twenty species were found among aquatic vegetation, 13 practically all the time and the remaining 8 part of the time. The preference for vegetation is presumably due to the abundance and variety of the food supply there and the shelter afforded by it. The north part of the lake, represented by stations 60 and 70, with as great a growth of vegetation as other parts of the lake, might be expected to have as great a number of species as the other sections, but only 8 species were taken there. The higher temperature of the water during the summer, and the shallowness of the water of the north part of the lake, are probably factors. An analysis of the water at stations 60 and 70 showed a pH of 5.94 and 5.91, respectively. On the other hand, the water at stations 30 and 100 showed a pH value of 6.64 and 6.71, respectively. Thus the greater acidity of the water in the lake in the north part may be a factor in limiting the number of species found there.

SYSTEMATIC LIST OF FISHES COLLECTED, WITH HABITATS AND RELATIVE ABUNDANCE

LEGEND: C, common; I, infrequent; F, frequent; R, rare; X, Cherry creek only; Z, Cherry creek

Order, Family, Genus and Species.	Cherry Creek	Habitats. Weedy	Mud	Open	Rock	Sand
ORDER RHOMBOGANOIDEA						
FAMILY LEPIDOSTIDÆ						
Lepidosteus osseus (L.)						
Long-nosed gar	X	C	F	......	......	F
ORDER ISOSPONDYLI						
FAMILY DOROSOMIDÆ						
Dorosoma cepedianum (Le Sue.)						
Gizzard shad	Z	......	C	F	......	......
ORDER EVENTOGNATHI						
FAMILY CATOSOTOMIDÆ						
Megastomatobus cyprinella (Cuv. and Val.)						
Red-mouth Buffalo	Z	F	C	......	......	......
Carpiodes carpio (Raf.)						
Common carp	X	F	C	......	......	......
Catostomus commersonnii (Lac.)						
Common sucker	Z	......	......	F	C	C
Moxostoma erythrurum (Le Sue.)						
Red horse	Z	......	......	......	F	C
FAMILY CYPRINIDÆ (Le Sue.)						
Cyprinus carpio L.						
German carp	X	F	C	......	......	......
Hybognathus nuchalis (Ag.)						
Silvery minnow	Z	......	C	......	......	I
Hyborhynchus notatus (Raf.)						
Blunt-nosed minnow	Z	F	C	......	......	......
Semotilus atromaculus (Mitch.)						
Horned dace	X	......	......	......	F	C
Notemigonus crysoleucas (Mitch.)						
Golden shiner	Z	C	C	......	......	I
Notropis nux (Meek)	Z	F	I	I	......	C
Notropis deliciosus (Gir.)						
Straw-colored minnow	Z	......	I	F	......	C
Notropis lutrensis (Bai. and Gir.)						
Red-finned minnow	Z	......	I	F	......	C
Hybopsis storerianus (Kirt.)						
Storer's chub	Z	......	......	......	I	C

SYSTEMATIC LIST OF FISHES—CONCLUDED

Order, Family, Genus and Species.	Cherry Creek	Habitats.				
		Weedy	Mud	Open	Rock	Sand
ORDER NEMATOGNATHI						
FAMILY SILURIDÆ						
Ictalurus furcatus (Le. Sue.)						
Blue cat	Z	......	F	......	F	......
Ictalurus punctatus (Raf.)						
Channel cat	Z	F	F	F	......	......
Ameiurus natalis (Le Sue.)						
Yellow bullhead	Z	F	C	F	......	......
Ameiurus melas (Raf.)						
Black bullhead	Z	F	C	F	......	......
Ameiurus melas catulus (Raf.)						
Black bullhead	Z	C	C	F	I	I
Loptops olivaris (Raf.)						
Mud cat, yellow cat	Z	......	R	......	......	......
ORDER CYPRINODONTES						
FAMILY CYPRINODONTIDÆ						
Fundulus notatus (Raf.)						
Top minnow	X	C	......	......	......	F
ORDER ACANTHOPTERI						
FAMILY CENTRARCHIDÆ						
Pomoxis annularis (Raf.)						
White crappie	Z	C	F	F	I	I
Pomoxis sparoides (Lac.)						
Black crappie	Z	C	F	F	I	I
Apomotis cyanellus (Raf.)						
Green sunfish	Z	C	.....	I	F	F
Allotis humilis (Gir.)						
Orange-spotted sunfish	Z	C	......	......	F	F
Helioperca incisor (Cuv. and Val.)						
Bluegill	Z	C	F	I	F	F
Eupomotis gibbosus (L.)						
Common sunfish	Z	C	F	......	F	F
Micropterus dolomieu (Lac.)						
Small-mouthed bass	Z	......	......	......	R	R
Aplites salmoides (Lac.)						
Large-mouthed black bass	Z	C	F	C	......	F
FAMILY PERCIDÆ						
Perca flavescens (Mitch.)						
Yellow perch	Z	C	F	F	F	F
FAMILY SCIANENIDÆ						
Aplodinotus grunniens (Raf.)						
Fresh-water drum	Z	C	.....	......	F	I

THE FOOD CHAIN OF THE BLACK BASS

Food is one of the most important factors in the life of fish, and in the Mineral Lake region as in other communities, the species of fish are arranged in food chains which combine to form a whole food cycle.

The black bass was selected because it is one of the largest predatory fishes of the lake (*6*), because it is fairly common, and all sizes have been taken over all kinds of bottom and at all depths in all parts of Mineral Lake.

Forty-two specimens of this fish were examined in order to determine their food (Fig. 2). In general the principal food consisted of Storer's chubs, golden shiners, blunt-nosed minnows, silvery minnows, common sunfishes, black bullheads, gizzard shads, and large aquatic insects. It is interesting to note that in seven large specimens, part of the food was found to consist of young snapping turtles. These turtles are very abundant in the lake, and due to the number found in various stomachs of the black bass, it may be concluded, that in this lake, for at least part of the year, the young snapping turtles furnish food for the black bass.

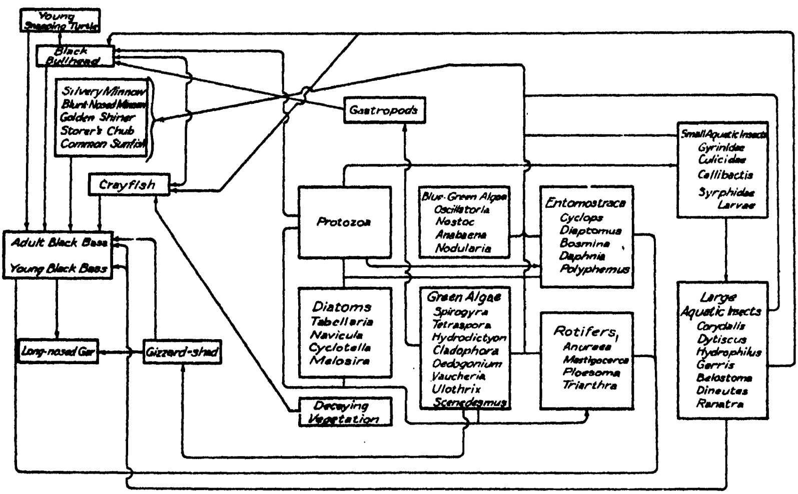

FIG. 2. Diagram of food chain of black bass. Arrow points from prey to predator.

Ten specimens of each of the smaller fishes found in the stomachs of the black bass were examined to determine the principal food consumed by them (Fig. 2). This food (*2*, *8*) was found to consist mainly of gastropods, small aquatic insects, large aquatic insects, entomostraca, rotifers, diatoms, (*7*) and green and blue-green algæ (*11*). Specimens of the fish eaten by the black bass, with small and large aquatic insects, were placed in an aquarium, 4 x 3 x 1.3 ft., in order to verify and observe their feeding habits and food.

SUMMARY

Mineral Lake is one of the smaller bodies of water in southeastern Kansas. The bottom of the lake is composed of mud, silt, sand, and some gravel. The prevailing southwesterly winds sweep over the lake continuously, keeping

the water well oxygenated at all times. The acidity of the water in the north part of the lake may be an inhibiting factor for a number of species of fishes. Thirty-two species, divided among 6 orders, 9 families, and 27 genera are now found in the Mineral Lake region. The black bass were found to be feeding upon smaller fishes, crustacea, and larger aquatic insects, which in turn were feeding upon small aquatic insects, entomostraca, protozoa, and algæ. The principal fishes eaten by the black bass were Storer's chub, golden shiner, blunt-nosed minnow, gizzard-shad, silvery minnow, and black bullhead. At certain times of the year, the young snapping turtles are eaten.

The biological environment is well adapted to support a varied and abundant fish fauna. The plankton and invertebrate life is found in abundance, and each is so distributed as to meet the needs of fish life.

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Notes on Some Cave Bats of Kansas

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The occurrence of bat caves in Kansas has been known by only a few persons. Apparently the only reference in literature is that given by Vernon Bailey in his "Mammals of New Mexico," North American Fauna No. 53, 1931, p. 387, where he states: "in a cave near Sun City, Kan., hundreds were found (*Myotis velifer incautus*) by Theo. H. Scheffer, on March 8, 1911, in a largely dormant condition."

With the intention of exploring this cave, a collecting trip was organized, and in company with Hobart Smith, the writer left for Sun City, September 1, 1933. Here we located and explored this cave and some 15 other caves and sinkholes south of Sun City, Kan.

The caves of this region occur in the Medicine Lodge gypsum, which caps the hills of this country. This formation is from 27 to 30 feet thick. The region is semiarid. The elevation varies from 1,900 feet in Barber county to 2,200 feet in Comanche county.

The openings of the sinkholes, through which one must descend by the aid of a rope, are some 15 to 20 feet deep. The caves are stream beds which are fed by surface water during the rainy season. They are generally long, but of small diameter, in many cases so narrow that one must slide along on his side some 200 or 300 feet before gaining entrance to a room that will permit one to stand erect.

We spent three days exploring the country just south of Sun City and collecting bats in that region. On the afternoon of September 4, we heard of some caves near Belvidere, Kan., but were unable to locate them. The country was explored south of Belvidere to Arrington, Kan. Here we met Mr. C. T. Brooks, who gave us much information in regard to caves of that region. He advised us to examine Swartz Canyon, since our time was limited. We visited Swartz Canyon September 6, finding some 12 caves and large sinkholes. That afternoon we visited the Marehew cave in Woods county, Oklahoma. We learned of many other regions with caves and sinkholes which we plan to examine in the near future.

A return trip was made November 3 to 5, inclusive, by Hobart Smith, A. B. Leonard and myself, to study the bats during hibernation.

A list of the bats collected together with notes concerning their habitat follows. The specimens collected are in the University Museum of Birds and Mammals, at Lawrence.

Myotis velifer incautus (J. A. Allen)

This bat was found to be the most common in Barber and Comanche counties. Soon after sundown large numbers were observed feeding over the high prairie along Medicine and Salt Fork rivers. Also many were seen at Bear, Cave, Mule and Owl creeks. Soon after dusk they would leave the prairie and feed along the valleys. Four were collected, September 2, in a tunnel by the Natural Bridge on Bear creek. Here they were in company with a group of *Antrozous bunkeri*. About 50 were taken September 3 at the Havard cave four miles southwest of Sun City. Here the bats were hanging

in a single group of 300 or more and took flight at the approach of our light, but were easily caught with nets. While these bats were not found occupying Dancer's cave, on September 3, a rat snake, *Elaphe læta,* containing a freshly swallowed *Myotis velifer incautus* was found on the floor of a small room in the cave. Another *Elaphe læta,* which was apparently in search of bats, was taken September 6 from a crevice in the roof of a cave in Comanche county.

We revisited the Havard cave November 3, and found *Mytois velifer incautus* in large numbers in a nearly dormant condition. The bats were hanging to the ceiling at a distance of only three to five feet above the stream which ran through the cave. They were not found inhabiting the higher ceilings of the drier rooms. The temperature of the Havard cave, November 3, at the water's edge was 10.5° C., and 16° C. at the ceiling of the higher rooms. The bats were breathing rapidly, approximately 92 times a minute, as counted by Mr. Leonard. Hundreds of bats were observed November 3 in Triple Arch cave, six miles south of Sun City, or a quarter of a mile north of Dancer's cave, and also in the Double Entrance S cave November 4 in Swartz Canyon, four miles northwest of Aetna, Kan., in Comanche county. In all the caves the bats were found close to the damp floor, hanging singly or in small groups ranging up to nearly 50 in number. The different sexes were not segregated. Specimens showing two color phases were observed and collected.

Myotis lucifugus lucifugus (Le Conte)

The little brown bat is apparently only a straggler in this region. A melanistic specimen, identified by Dr. G. S. Miller, Jr., was collected September 3 at the Havard cave from among a group of *Myotis velifer incautus.* Another specimen, a male, was taken November 4 in the Double Entrance S cave in Comanche county, hanging by himself on the ceiling among scattered groups of *Myotis velifer incautus.*

Pipistrellus subflavus subflavus (F. Cuvier)

These little bats were not common in any of the caves. They were found singly, and in the most obscure places, occuping a much drier habitat than *Myotis velifer incautus.*

A male was taken September 2 in the "gyp" spring one-half mile north of the Natural Bridge on Bear creek. Another male was taken September 3 in Dancer's cave, 6¼ miles south of Sun City, and on September 7 a female was taken in the Havard cave. All three of these bats were found in a semi-dormant condition, clinging by both hands and feet to the sides of the caves, with heads up, a posture not observed in any of the other bats found in the caves. Two females and two males were collected November 3 in the Havard cave. All of these were found on the side of the cave clinging by both hands and feet, but only one with head up. Eight males and one female were collected November 5 in Cave Spring cave, 6 miles south of El Dorado, Butler county, Kansas, on U. S. highway 54. These nine bats were scattered through the cave for a distance of 1¼ miles. No two were found together, but all clinging to the side of the cave with head downward. This cave is a large limestone cavern in the Permian, with a stream running the full length.

Eptesicus fuscus fuscus (Beauvois)

The big brown bat was found only in the Double Entrance S cave in Swartz Canyon, on the south side of Salt Fork river, Comanche county, four miles northwest of Aetna, Kan. Two females were taken November 4 hanging together close to the damp stream bed; one male hanging alone and another male hanging in a crevice of the roof with a male *Myotis velifer incautus.*

Corynorhinus rafinesquii pallescens (Miller)

This long-eared bat showed little tendency to be gregarious in habit. Only females were found together. We succeeded in catching a male September 2, in Fallen Arch cave, three quarters of a mile south of the Natural Bridge on Bear creek. Seven of these bats were observed in the caves of Barber county in September. They were always hanging by one foot and would fly at the slightest approach of our light, darting in among the rocks or out of the many openings. On the afternoon of September 6, 31 were taken at the Marehew cave, one-half mile south of the Kansas line in Woods county, Oklahoma. Seven were males, all of which were captured with a net while flying in the cave. A large number of males were observed, which flew at our approach. Two large groups of females were found. These started to fly at the approach of our light, but 5 were caught from one group and 19 from the other with a single sweep of the net.

Two females were taken November 2 from a sinkhole in Barber county, one-eighth mile northeast of Dancer's cave. Three females were taken November 4 in Comanche county, from the Double Entrance S cave. All were found singly on the underside of large rocks very close to the stream bed.

These bats are intermediate between *Corynorhinus r. rafinesquii* and *C. r. pallescens,* but show closer relationship to the latter.

Antrozous bunkeri Hibbard

The first place that we explored was a tunnel at the Natural Bridge, 7 miles south of Sun City, on the afternoon of September 2. The south entrance of the tunnel is about four feet high and three feet wide. Entering the tunnel from the south, we found a low ceiling for the first 130 feet; at this point the ceiling became higher, ranging from 6 to 10 feet. A distance of 168 feet from the south entrance we came upon a group of *Antrozous bunkeri* hanging from the ceiling. As we came nearer to them two bats (*Myotis velifer incautus*) flew from the group into the north end of the tunnel. The bats paid no attention to us. They were closely packed, some hanging to others which were wedged in a crack. As we started collecting them from the ceiling, they attempted to crawl away over the surface, but made no effort to fly, neither did they attempt to bite as did the other bats collected. In the group of *Antrozous* were found, and taken, two *Myotis velifer incautus.* A few of the *Antrozous* were dislodged and fell to the floor, but only one now and then tried to escape. Twenty-five specimens were collected, consisting of 12 adult females, 10 immature females and 3 immature males. *Antrozous* was never found again on our collecting trips. The quantity of guano on the floor under the bats indicated that it was their first day in that part of the tunnel. About 20 feet from the north entrance was found a small area of freshly scattered guano

belonging to *Antrozous*. It was apparently evident that the bats had only spent two days in this tunnel.

Tadarida mexicana (Saussure)

At the Marehew cave, one-half mile south of the Barber-Comanche county line, in Woods county, Oklahoma, September 6, we found the free-tail bat in large numbers. That evening at sundown they emerged from the cave in large clouds, flying to the northeast over Kansas, many stopping to feed over the Salt Fork river, and a large number flying northward out of sight. We were told at the Marehew ranch that these bats feed northward to the Arkansas river. Upon return to Aetna, Kan., a mile north of the Salt Fork river, that evening many were observed flying. One of these was shot and is now in the University of Kansas Museum of Birds and Mammals, No. 9315. On our return to the Marehew cave November 4, no free-tail bats were found. Apparently they had migrated southward for the winter. It is known that they have occupied the cave in the summer since days of the earliest settlers, but nothing is known of their winter habits in this region.

Two New Genera of Felidæ from the Middle Pliocene of Kansas[1]

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(PLATES IV, V, VI)

INTRODUCTION

Through the courtesy of Dr. H. H. Lane, curator in charge of the Kansas University Museum of Vertebrate Paleontology, I have been given the opportunity of studying and describing the remains of two apparently new forms of the Felidæ.

Kansas has been noted for its rich fossil deposits for many years, though only within the past ten years has attention been paid to the Pliocene deposits, with the exception of the once famous Long Island quarry. During the past forty years a few scattered bones of Pliocene age have made their way into the Museum of Vertebrate Paleontology, some of which were picked up by our own expeditions. In the summer of 1924, Mr. H. T. Martin opened the first Pliocene quarry (known as the Edson Beds—North Quarry) with the purpose of collecting a Pliocene fauna for the Museum. He returned to this quarry in 1926, and also located and opened other quarries of this age. The summers of 1928, 1930 and 1931 were spent in collecting from Pliocene deposits of western Kansas.

Due to Mr. Martin's death, there has been a delay in the studying of this fauna.

Much credit is due Prof. M. K. Elias for his study of the Tertiary beds of Kansas, and the placing of these beds in relation to one another in the geologic sections. I am greatly indebted to Professor Elias for the privilege of publishing a copy of the two generalized sections of the Pliocene formation of Kansas. The purpose of these sections is to show the relation of the known Pliocene fossil beds in the state from which we have collected.

In the diagram the Edson beds of Sherman county, Kansas, have been placed provisionally in the geologic section of Wallace county, to show their relation to the Rhinoceros Hill quarry. The Edson beds rest unconformably upon the Pierre shale, but due to the fact that it is a local deposit and the absence of fossil seeds, it is impossible to correlate it directly with the other beds, except in its relation to the Pierre shale. There is some question as to the exact age of the deposit; although referred to here as the Middle Pliocene, it may actually prove to be uppermost Lower Pliocene.

The type locality of *Pratifelis martini* (NW¼ of sec. 1, T. 15 S., R. 38 W) is designated as the Lost Quarry. The exact relation of this deposit to the Ogallala formation is unknown, but it is at least thirty feet below the Algal limestone, and not lower than the Long Island fauna. The deposit was discovered in the summer of 1911 by Mr. Martin while collecting with team and wagon along the tributaries of the South Fork of the Smoky Hill river. Mr.

1. A thesis submitted to the Department of Zoölogy and the Faculty of the Graduate School of the University of Kansas in partial fulfillment of the requirements for the Degree of Master of Arts. March 21, 1934.

Martin marked the locality, but it was not found again until the summer of 1928 with the aid of Messrs. Grover and De Tilla of Wallace, Kan., although much time had been spent in search of it during previous years. In the summer of 1928 the quarry was opened, and at the present time it promises to yield one of the richest faunas of any quarry yet worked in western Kansas.

Pratifelis martini gen. et sp. nov.

(Figs. 3, 4)

TYPE. No. 3156, University of Kansas Museum of Vertebrate Paleontology; left mandibular ramus bearing P_3, P_4, M_1 and alveolus of C; from Middle Pliocene, Wallace county, Kansas, in the NW¼ of sec. 1, T. 15 S, R. 38 W.; Lost Quarry. Collected during the summer of 1911, by H. T. Martin.

GENERIC DIAGNOSIS. Dental formula $I\frac{3}{3}$ $C\frac{1}{1}$ $P\frac{3}{2}$? $M\frac{1}{1}$; M_1 with well-developed talonid; metaconid lacking; anteroposterior diameter of protoconid and paraconid equal; deep and broad carnassial notch; P_4 with strongly developed posterior heel with lateral accessory cusp; P_3 slightly reduced, with well-developed posterior heel with accessory cusp; short diastema; symphysis short; deep grooves in rami along inner side of canines. (*Pratifelis*, from *pratum*, field or plain, and *felis*, cat.)

DESCRIPTION OF TYPE. (See Table 1 for measurements.) M_1, strong and well developed; the anteroposterior diameter of protoconid and paraconid equal; paraconid situated well forward and partly on the lingual side of P_4; metaconid lacking; talonid well developed; cingulum slightly developed; carnassial notch deep and broad, depth 2.5 mm., width at top of notch 1.5 mm., width at base of protoconid and paraconid 1 mm. The enamel on the posterior side of protoconid is missing from tip of crown to talonid, giving the paraconid a more slender appearance. P_4 is situated in line with the axis of the jaw. The anterior basal tubercle is missing; posterior cusp is situated on a strong and well-developed heel, whose anteroposterior length is 5 mm. The greatest transverse diameter of the tooth is across the posterior cusp. P_3 is situated at a slight angle to the axis of the jaw with the anterior root closer to the lingual side of the jaw than the posterior. This tooth is but slightly reduced and it possesses a well-developed posterior cingulum. The posterior cusp is situated on a well-developed heel with the greatest transverse diameter of the tooth in the plane of this cusp, as in P_4. P_3 and C are separated by a greatly reduced diastema, 8.5 mm. Due to the nearly vertical inner surface of the jaw at this point and the concave outer surface of the diastemal region, a very narrow ridge is formed between P_3 and C. There is no evidence of P_1 and P_2, but the alveolus of the canine indicates a well-developed tooth. The incisors must have been small and closely crowded because of the narrow width of the rami at the symphysis. The symphysis is short; its posterior dorsal border is located in line with the posterior border of the alveolus of the canine. The symphysis slopes slightly toward the base, and extends backward nearly to the middle of the diastema. A deep groove on each side extends from the incisors back along the inner edge of the jaw on the lingual surface. It is 5 mm. from top of the alveolus of the canine to the bottom of the groove. The symphysis appears to have formed a slight ridge between the two grooves.

TABLE 1. Measurements (in millimeters) of specimens of three genera of Felidæ

	Pratifelis martini type...	*Pseudælurus marshi* type...	*Pseudælurus intrepidus*.....	*Metailurus major* type...
Length of tooth series (P_3, P_4, M_1)..............	44.5	36.0	44.5	......
Length of diastema between C and P............	8.5	8.6	14.8	18.5
P_3, anteroposterior diameter....................	12.0	9.5	11.6	15.5
P_3, greatest transverse diameter.................	5.0	......	......	8.4
P_4, anteroposterior diameter....................	14.5?	12.5	14.8	21.0
P_4, greatest transverse diameter................	6.0	......	.....	9.3
M_1, anteroposterior diameter....................	29.5	16.0	19.6	23.2
M_1, greatest transverse diameter..............	8.0	......	......	10.7
M_1, transverse diameter across paraconid.......	8.0	......	......	......
M_1, anteroposterior diameter of paraconid........	8.5	......	......	......
M_1, anteroposterior diameter of protoconid.....	8.5	......	......	......
M_1, anteroposterior diameter of talonid........	3.5	......	......	......

REMARKS. The jaw is very light relative to the heavy and well-developed dentition. It is so broken that all foramina are missing. P_4 is situated well to the outer side of the jaw, so that the tooth projects slightly over the side, as in *Felis,* but the jaw is so narrow that P_3 is situated well to the inner side, even to a greater extent than in *Lynx.* The jaw indicates a short-faced cat with a large M^1 and a reduced upper anterior premolar region.

In order to facilitate comparison with other more or less related felids, a number of differential characters are given for five genera in the table on the following page.

Attention should be called to the development of P_3 and P_4 in the line from *Nimravus* to *Felis* in the relation of the anterior and posterior transverse diameter to the anteroposterior diameter. In *Nimravus* P_3 is narrow and the posterior transverse diameter is slightly greater. P_4 is a well-developed tooth with the posterior transverse diameter exceeding that of the anterior transverse diameter. A crown view of P_3 and P_4 shows them to be rather triangular with the base line posterior and the apex anterior in position. In the line of development up to *Felis* we find that P_3 and P_4 become more massive, with but slight difference between the anterior and posterior transverse diameters; there is also a development of accessory cusps upon the anterior and posterior basal tubercles.

Pratifelis presents very primitive characters in P_3 and P_4 in that the teeth have a small anterior transverse diameter in proportion to their anteroposterior diameter, with broad, enlarged posterior tubercles; from the side view the margins of the median cusp of these teeth drop rapidly, being approximately vertical in the lower half of their course, thus forming a sort of a pentagon, whereas in *Felis* this cusp is more nearly broadly triangular.

DIFFERENTIAL CHARACTERS OF FIVE GENERA OF FELIDS

Nimravus Lower dentition, 3.1.3–2.2–1	*Pratifelis* Lower dentition, 3.1.2.1	*Pseudælurus* Lower dentition, 3.1.3–2.1–2	*Metailurus* Lower dentition, 3.1.2–3.1	*Felis* Lower dentition, 3.1.2.1
P_3: small anterior basal tubercle; well-developed heel, with no lateral accessory cusp.	P_3: small anterior basal tubercle; well-developed heel with rudimentary lateral accessory cusp.	P_3: small anterior basal tubercle; heel small to much reduced with small accessory cusp.	P_3: well developed anterior basal tubercle with small posterior lingual accessory cusp; small posterior heel with accessory cusp.	P_3: well-developed anterior basal tubercle, with small accessory cusp; posterior heel with cusp.
P_4: anterior basal tubercle and heel distinct without accessory cusp; weak cingulum.	P_4: light anterior basal tubercle; heel strong, with small lateral accessory cusp; weak cingulum.	P_4: anterior basal tubercle; heel with small accessory cusp; supported by cingulum.	P_4: anterior basal tubercle with well-developed cusp; heel with well-developed cusp; very strong cingulum.	P_4: broad anterior basal tubercle with well-developed cusp; strong posterior cingulum.
M_1: heavy; strongly developed posterior root; well-developed heel; deep and broad carnassial notch; paraconid partly crowded on lingual side of P_4.	M_1: heavy; strongly developed posterior root; well-developed heel; deep and broad carnassial notch; paraconid partly crowded on lingual side of P_4.	M_1: medium; reduced posterior root; vestigal heel; deep and partly closed carnassial notch; paraconid slightly crowded on lingual side of P_4.	M_1: medium; reduced posterior root; vestigal heel; deep and partly closed carnassial notch; paraconid slightly crowded on lingual side of P_4.	M_1: medium; greatly reduced posterior root; deep and closed carnassial notch; paraconid not crowding P_4 on lingual side.

A true cat from the Middle Pliocene would naturally be expected to possess characters intermediate at least between those of *Pseudælurus* and *Felis*. In *Pratifelis*, however, the primitive characters in the dentition are dominant, pointing to a direct development from *Nimravus* rather than from *Nimravus* through *Pseudælurus*. It is natural to expect *Pseudælurus* to persist into the Middle and Upper Pliocene even after it had given rise to *Felis*, but it would not be logical to expect it to give rise to a more primitive line of cats than itself. One must then look to *Nimravus* as the ancestral stock which probably persisted for a longer period of geologic time as a generalized primitive cat than has been hitherto recorded.

Pratifelis presents the following characters in common with *Nimravus:* M_1, with well-developed heel; anteroposterior diameter great; paraconid strongly developed and partly situated on inner side of posterior heel of P_4; deep and broad carnassial notch; posterior root strongly developed. P_4 with well-developed median cusp distinctly separated from posterior heel; posterior root strongly developed; crown of tooth greatly narrowed anteriorly.

Diastema from P_3 to C short, 8.5 mm.; P_2 and P_1 entirely lacking; posterior accessory cusps present on P_3 and P_4. These are the only characters suggesting a relationship to the *Pseudælurus-Felis* line.

In common with *Metailurus major* Zdansky, *Pratifelis* has the similar deep furrow in the median line between the two rami, and also lacks P_1 and P_2. The diastema of *Pratifelis* between C and P_3 is 8.5 mm., while that of *M. major* is 18.5 mm. Zdansky ('24) states that P_3, as P_4 also, is set a little obliquely to the axis of the jaw. P_4 of *Pratifelis* is situated in line with the axis of the jaw. M_1 of *M. major* presents a reduced pad-shaped talonid, while that of *Pratifelis* is strongly developed. The anteroposterior diameter of M_1 in *Pratifelis* is 6.3 mm. greater than that of *M. major*.

Adelphailurus kansensis gen. et sp. nov.

(Figs. 1, 2 and 3)

TYPE. No. 3462, University of Kansas Museum of Vertebrate Paleontology; anterior portion of skull consisting of premaxillaries, maxillaries, most of palatines, and complete dentition with the exception of right molar; from Middle Pliocene, near base of the Ogallala formation, Sherman county, Kansas; sec. 25, T. 10 S., R. 38 W.; Edson Beds. Collected by H. T. Martin and party during the summer of 1924.

GENERIC DIAGNOSIS. Dental formula $I\frac{3}{3}$ $C\frac{1}{1}$ $P\frac{3}{2?}$ $M\frac{1}{1}$; P^4 with prominent parastyle; paracone and metacone strongly developed and separated by a deep carnassial notch. P^2 vestigial; situated at an oblique angle to line of dentition. Diastema between P^3 and P^2 small. Greatly reduced diastema between P^2 and C, 1 mm. Probably P^2 may be present or absent. Canines, well developed, possessing only posterior cutting edge, slightly serrated near base, deep groove present behind anterointernal edge and extending nearly to tip. The nasomaxillary processes are broad, rounded at the end, and nearly parallel. (*Adelphailurus* from *Adelphos*, brother, and *ailuris*, cat.)

DESCRIPTION OF TYPE. (See Table 2, for measurements.) The anterior portion of the skull represents that of a cat with a broad, high face. The maxillaries are heavily developed, evidently for the retention of the large canines. The root of the canine is 43 mm. long. The nasomaxillary process is broad

not tapering at the end where it meets the frontals. The maxillary is rounded at the frontal end and apparently forms the anterior border of the orbit. The nasomaxillary processes do not converge as in the puma or cheeta, but are parallel, giving a very broad face to the cat. The infraorbital foramina are narrow, elongate ovals, situated 23 mm. above the anterior root of P^4, while in *Pseudœlurus quadridentalus* (Filhol, '91, p. 77) they are situated 16 mm. above the alveolar border of the middle portion of P^3. The height of the premaxillary processes along the maxillaries is unknown, as they are broken. The premaxillary process extends over one-half the anterior surface of the canine at the alveolar region, as in *Felis leo*. Except for the anterior margin, the anterior palatine foramina are missing, due to the absence of that portion of the premaxillaries and the palatine process of the maxillaries. The premaxillaries are deeply grooved, in front of the anterior palatine foramina, with the lateral edges of the groove, anteriorly parallel, reaching to the incisors. The lateral edges are in line with the outer borders of the alveoli of the second premolars. The anterior borders of the foramina are 14 mm. from the base of I^2. The width of the groove at the anterior edge of the foramina is 11.5 mm. The anterior posterior palatine foramina are located opposite the anterior border of P^4 and are situated in the palatal process of the maxillaries, the posterior border of the foramina just meeting the suture of the palatines. There are two small posterior posterior palatine foramina on each side, situated behind the large anterior posterior palatine foramina.

DENTITION. The teeth are nearly perfect; the anterior part of the left P^4 is broken, and right M^1 missing. The incisors are situated in a straight line and are strong and deeply rooted. I^1 and I^2 are considerably deeper anteroposteriorly than wide, with I^2 slightly the larger. I^3 is larger than that of *Felis oregonensis hippolestes*. It is deeply grooved on the lateral posterior surface for the reception of the lower canine. A diastema of 5 mm. separates it from the base of the canine.

The upper canines are complete. Their slightly convex, almost flat, anterior surface merges with the lateral surface through a marked convexity, which ends at the posterior cutting edge. The lingual side of the canines is almost a plane surface, with the exception that the anterior internal border, which forms a sharp shearing surface in contact with the lower canine, is marked by the presence of a deep groove close to and parallel to this margin. This groove becomes more shallow as it approaches the point of the canine, disappearing about 17 mm. from the tip. Posterior to the groove the inner surface of the canine becomes slightly rounded, meeting the lateral surface to form the sharp posterior blade which is slightly serrated near the base. The canine possesses only the posterior cutting edge. There is no indication of an anterior cutting edge, as the anterior surface is broad, forming a flattened curve which is continuous with the buccal side.

P^2 is separated from the canine by a diastema of 1 mm. It is very small, and so crowded by the canine that it is situated at a slight angle to the line of dentition. A diastema of 2 mm. separates P^2 and P^3.

P^3 is well developed. The protocone is heavier and higher than in the puma. The protocone curves inward and slopes slightly posteriorly. The tritocone is well developed. The tooth possesses a strong cingulum on the posterior base which is highly upturned.

P^4 is larger than in the puma, with all parts more distinctly developed. On the anterolateral side of the parastyle is a well-developed cingulum. The paracone is nearly perpendicular to the base of the crown. The metacone is strong and well developed, being nearly as high as the paracone. The carnassial notch is deep and well developed, but not so nearly closed as in *Felis*. The protocone is situated more posteriorly in relation to the parastyle than in the puma. The top of the protocone is in a line between the parastyle and paracone. This is due to the position of the internal root of P^4, which is slightly shifted posterior to the anterior lateral root. Between the crown of the protocone and the base of the paracone is a worn place for the reception of the cone of the accessory cusp of the opposing P_4.

M^1 is double rooted and is nearly two-thirds larger than in the puma, or in the ratio of 5:3. It may be distinctly seen from the outer side in the line of dentition.

TABLE 2.—Measurements (in millimeters) of the type of *Adelphailurus kansensis*.

Length, anterior side of canine at alveolus margin to posterior side of P^4	64.0
Length, anterior side of P^2 to posterior side of P^4	46.0
Width, from median side of I^1 to lateral side of I^3	11.0
I^1, anteroposterior diameter	3.0
I^1, transverse diameter	2.0
I^2, anteroposterior diameter	3.5
I^2, transverse diameter	3.0
I^3, anteroposterior diameter	5.5
I^3, transverse diameter	4.5
Diastema between posterior side of I^3 alveolus and anterior side of canine alveolus	5.0
C, anteroposterior diameter at alveolar margin	17.5
C, transverse diameter at alveolar margin	11.5
C, length, alveolus margin to crown	43.0
Diastema between C and P^2	1.0
P^2, anteroposterior diameter	4.5
P^2, transverse diameter	3.0
Diastema between P^2 and P^3	2.0
P^3, anteroposterior diameter	15.5
P^3, transverse diameter	8.0
P^4, anteroposterior diameter	25.0
P^4, transverse diameter across protocone	12.0
P^4, length of metacone	10.0
P^4, length of paracone	10.0
P^4, length of parastyle	5.0
M^1, length	8.0
M^1, breadth	4.0
Distance, from anterior edge of premaxillary in front of I^1 to posterior edge of maxillary posterior of M^1	83.0
Height, of nasal process of the maxillary from alveolus of canine	72.0
Width, of nasal process of the maxillary at top of lacrymal	27.0
Width, of premaxillary from median suture to suture forming alveolus of canine	21.0

Height, of lower border of the infraorbital foramen above the border of the alveolus of P^3 .... 23.0
Dorsoventral diameter of the infraorbital foramen 13.0
Transverse diameter of infraorbital foramen 5.0

REMARKS. The dentition represents that of an early, highly specialized felid. The well-developed parastyle of P^4 and the tritocone of P^3; the short diastema between C and P^2; and the highly specialized canines all separate it from *Pseudælurus*. The characters of P^3 and P^4 are truly felid with the exception of the carnassial notch, which is open instead of closed, a condition to be expected in the early Felidæ. The shortness of the diastema between P^2 and C indicates a high degree of specialization. The canine presenting only the posterior cutting edge with the rounded anterior surface is also a felid character.

In comparison with *Metailurus,* we find a contrasted difference in the canines. The canines of *Metailurus,* as described by Zdansky ('24), possess perfectly smooth inner and outer surfaces, also both posterior and anterior cutting edges, although both lack serration. *Adelphailurus* possesses only a posterior cutting edge slightly serrated at the base, with a deep groove behind the anterointernal edge. The small anterior cusp of P^3, spoken of by Zdansky in *Metailurus,* is not present in *Adelphailurus.* The protocone in *Metailurus* is situated more posteriorly than in *Adelphailurus.*

In *Pseudælurus, Metailurus* and *Felis* the upper canines diverge and are not in line with the top of the crowns of P^4, P^3, P^2, and I^3; also there is a diastema of considerable size between I^3 and C, which is enlarged by the divergence of the latter for the reception of the lower canines. In *Adelphailurus* the inner surface of the upper canines is in the line of the upper dentition, making a small diastema for the reception of the lower canines. A comparison of this skull with the skulls and lower jaws of other cats, shows that *Adelphailurus* must have possessed a mandible which, for its size, was comparatively narrow anteriorly, and with the lower canines greatly reduced in comparison with the upper ones. The lateral surface of the jaw must have possessed a slight concavity for the reception of the upper canines, but it probably lacked the flange, characteristic of the saber-tooth cats. Anteriorly the lower jaw apparently is of an entirely different shape from that of *Pseudælurus* and *Felis.*

Hence this cat possesses characters that might be expected in an evolutionary development between the Miocene *Pseudælurus* and the Pliocene *Felis;* as, for example, those shown by P^4 and P^3; though some primitive characters that are present in *Pseudælurus* are also found in the upper canines of *Adelphailurus.* But the presence of the true feline, P^4 and P^3, with the highly specialized canines, which, without doubt, affected the development of the lower jaw, would seem to give sufficient warrant for separate generic rank, a conclusion supported by the consideration that true *Felis* is known from the Lower Pliocene. It is my opinion that *Adelphailurus* was derived from the primitive *Felis* of the Lower Pliocene, as an aberrant branch.

Other faunal lists have been given for the Edson Beds in the past, but after further study it seems advisable to bring this up to date as much as possible, since it represents the richest deposit known in the Pliocene of Kansas. I am indebted to Messrs. R. A. Stirton and Curtis J. Hesse, University of California, Berkeley, Cal., for the identification of the material which they are

studying from this quarry. The following list comprises material associated with *Adelphailurus* in the Edson Beds in Sherman county, Kansas.

Amphibia
- Ambystomidæ
  - *Plioambystoma kansensis* Adams
  - *Anura* sp. indt.

Reptilia
- Chelydridæ
  - *Chelonia* sp.
- Testudinidæ
  - *Testudo* sp.

Aves
- Paludicoles
  - *Grus nannodes* Wetmore and Martin

Mammalia
- Carnivora
  - Mustelidæ
    - *Martinogale alveodens* Hall
    - *Plesiogulo marshalli* (Martin)
  - Canidæ
    - *Osteoborus cyonoides* (Martin)
    - *Vulpes* cf. *vafer* (Leidy)
  - Felidæ
    - *Machairodus* cf. *catocopis* Cope

Rodentia
- Mylagaulidæ
  - *Mylagaulus monodon* Cope
- Sciuridæ
  - *Sciurus* sp.

Artiodactyla
- Camelidæ
  - *Megatylopus gigas* Matthew and Cook
  - *Pliauchenia* sp.
- Tayassuidæ
  - *Prosthennops serus* (Cope)

Perissodactyla
- Equidæ
  - *Hipparion* cf. *montezumæ* (Leidy)
  - *Pliohippus* cf. *pernix* Marsh
  - *Calippus ansæ* Matthew and Stirton
- Rhinocerotidæ
  - *Aphelops* cf. *mutilus* Matthew

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EXPLANATION OF PLATES

PLATE IV

Stratigraphic distribution of the Tertiary vertebrate faunas in western Kansas.

PLATE IV

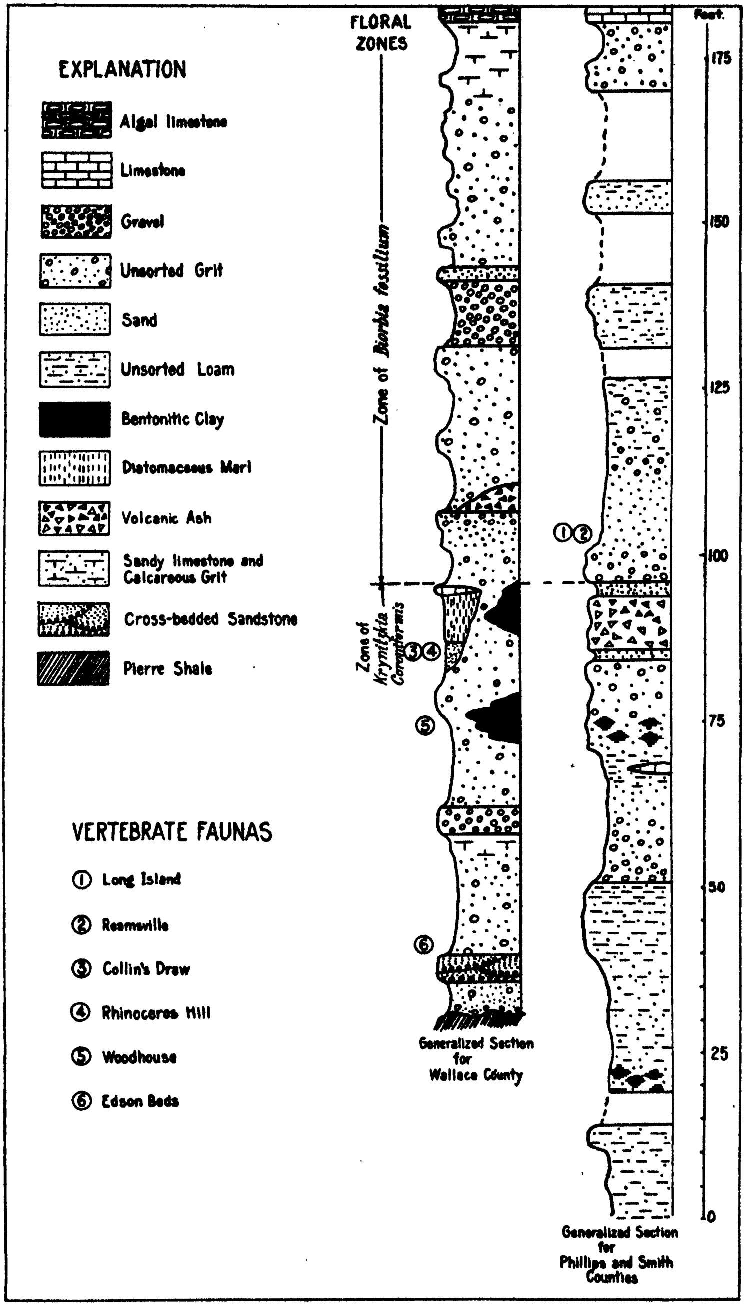
EXPLANATION
Algal limestone
Limestone
Gravel
Unsorted Grit
Sand
Unsorted Loam
Bentonitic Clay
Diatomaceous Marl
Volcanic Ash
Sandy limestone and Calcareous Grit
Cross-bedded Sandstone
Pierre Shale
VERTEBRATE FAUNAS
① Long Island
② Reamsville
③ Collin's Draw
④ Rhinoceros Hill
⑤ Woodhouse
⑥ Edson Beds
FLORAL ZONES
Zone of Biorbia fossilium
Zone of Krynitzkia Coroniformis
Generalized Section for Wallace County
Generalized Section for Phillips and Smith Counties
Feet
175
150
125
100
75
50
25
0

PLATE V

FIG. 1. *Adelphailurus kansensis*. Lingual view of right upper jaw, U. K. M. No. 3462, type from Edson Beds, Sherman county, Kansas. Natural size.

FIG. 2. *Adelphailurus kansensis*. Lateral view of right upper jaw, U. K. M. No. 3462, type from Edson Beds, Sherman county, Kansas. Natural size.

PLATE V

PLATE VI

FIG. 3. *Adelphailurus kansensis.* Occlusal view of anterior portion of skull, U. K. M. No. 3462, type from Edson Beds, Sherman county, Kansas. × 23/25.

FIG. 4. *Pratifelis martini.* Lateral view of left mandibular dentition, U. K. M. No. 3156, type from Lost Quarry, Wallace county, Kansas. Natural size.

FIG. 5. *Pratifelis martini.* Crown view of type specimen. Natural size.

PLATE VI

A New Cestode from a Bat

S. L. LOEWEN, Sterling College, Sterling

(PLATE VII)

Two strobilæ of a cestode of the family Anoplocephalidæ were taken from a red bat which appear to belong to an undescribed species. They undoubtedly are of the subfamily Linstowinæ Fuhrmann, 1907, and agree quite generally with the description given for the genus *Oochoristica* Lühe, 1899.

Oochoristica taborensis, new species

(PLATE VII, Figs. 1-8)

SPECIFIC DIAGNOSIS. *Oochoristica:* Strobila. Total length, 8.9 (6-5)[1] cm., gradually tapering from posterior end to scolex; maximum width, 1.4 (1.4) mm.; minimum width, 0.32 (0.37) mm.; number of distinct proglottids, 31 (21). Scolex unarmed, without rostellum, 0.32 (0.37) mm. wide, poorly differentiated from the neck. Suckers four, musculature poorly developed, 0.128 by 0.142 (0.132 by 0.156) mm. in diameter. Neck wider than scolex; strobilization becomes apparent about 0.42 mm. from the scolex. Early immature proglottids measure 0.25 (0.23) mm. long and 0.44 (0.45) mm. wide; mature proglottids measure in length 1.98 (2.34) mm., in width 1.178 (1.278) mm.; ripe proglottids are enormously elongated, the last one measures 12 (13) mm. in length and 1.4 (1.4) mm. in width. Genital pores marginal, alternating irregularly, always within 1/7 the length of the proglottid from its anterior end. Papillæ lacking. Excretory ducts distinct, large, unbranched except for the transverse canal at the caudal margin of the proglottid.

Male genitalia: Cirrus sac large and distinct, nearly spherical, 0.123 by 0.153 (0.122 by 0.140) mm. Cirrus 0.06 mm. in diameter. Testes spherical, 0.07 mm. in diameter, about 75 to a segment arranged in two regions, preovarian and postovarian, with about an equal number in each group. In the anterior region they extend from the ovaries to the level of the cirrus sac, while in the posterior region they lie lateral and caudal to the vitellaria. Vas deferens, first part considerably undulating, extends from the cirrus sac caudally along the median line to the midovarian region.

Female genitalia: Ovaries, irregularly and deeply lobed, lie in midregion of proglottid and cover an area of approximately 0.5 by 0.25 mm. each. Vitellaria symmetrically placed behind the ovaries, deeply lobed, and each occupying a space of ca. 0.20 by 0.24 mm. Vagina turns mesio-caudad from the cirrus sac and parallels the vas deferens in the median plane, extending to Mehlis' gland just cephalad to the vitellaria. No definite uterus observed; eggs encapsulated singly in parenchyma. Eggs, 33 by 39 mu, contain a well-developed hexacanth embryo which measures 25 mu in diameter.

Type specimen. U. S. Nat. Mus. Helm. Collection No. 8762.

1. The first figures are those of the type specimen with the respective measurements of the cotype given in parenthesis.

Type host. Primary: *Lasiurus borealis borealis* (Müller, 1776)[2], the red bat; author's host No. M-1. Secondary: unknown.

Habitat. Intestine.

Locality and date. Sterling, Kan., June 21, 1932.

Adult *Oochoristica* have been collected from reptiles and the mammalian orders Carnivora, Insectivora, Edentata, and Marsupialia. This is the first species of *Oochoristica* as well as of an anoplocephalid tapeworm to be described from the Chiroptera. Macy (1931) lists six cestodes from bats for the world and adds a seventh species. The complete list of species to date is as follows: *Tænia obtusata* Rud., 1819, *T. strobilus* van Beneden, 1873, *T. meander* von Linstow, 1903, *Hymenolepis acuta* (Rud., 1819), *H. decipiens* (Dies., 1850), *H. moniezi* Parona, 1893, *H. christensoni* Macy, 1931, and *Oochoristica taborensis* Loewen (present paper).

The species discussed in this paper as new agrees with the description given for the genus *Oochoristica*, except in that the excretory system does not show any secondary ramifications and in that the testes are distributed posteriorly and anteriorly to the female sex glands instead of posteriorly and laterally. The position of the genital ducts with reference to the excretory duct and lateral nerve could not be established because of the limited amount of material on hand. It is possible that with additional material available for careful study it will be necessary to place this species into another genus, possibly that of *Diochetos* Harwood, 1932, to which it shows several marked similarities. However, under present conditions it seems desirable to give it a place with the genus *Oochoristica*.

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2. Identification through the courtesy of the General Biological Supply House Identification Service.

EXPLANATION OF PLATE VII

FIG. 1. *Oochoristica taborensis*, scolex and neck.

FIG. 2. *Oochoristica taborensis*, mature proglottid. cp, cirrus pouch; ex, excretory duct; mg, mehlis' gland; ov, ovary; te, testes; va, vagina; vd, vas deferens; vi, vitelline gland.

FIG. 3. *Oochoristica taborensis*, ripe proglottid showing distribution of eggs.

PLATE VII

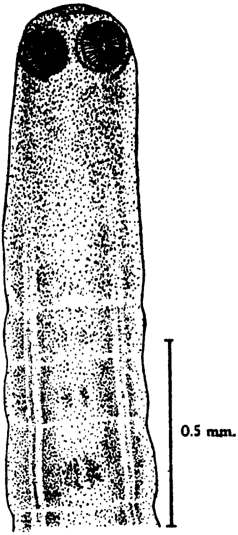

Fig. 1

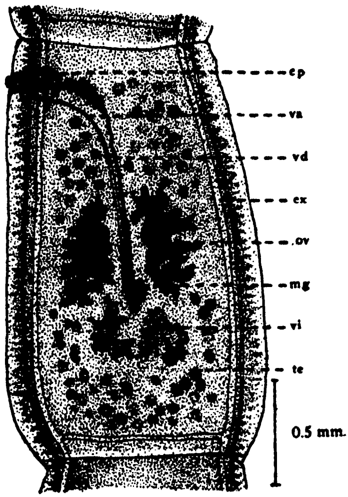

Fig. 2

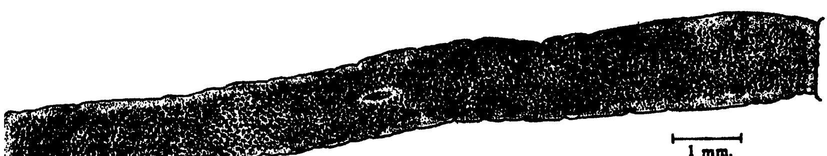

Fig. 3

Descriptions of New Lizards of the Genus *Sceloporus* from Mexico and Southern United States

HOBART M. SMITH, University of Kansas, Lawrence, Kan.

(PLATES VIII, IX, X)

The following descriptions are based largely upon specimens secured in Mexico and southern United States by Dr. Edward H. Taylor and myself during the summer of 1932. All catalogue numbers, unless otherwise indicated, refer to specimens in this collection. The type of *olivaceus* was collected by Doctor Taylor and John S. Wright during the summer of 1931. Some specimens from the collection in the Dyche Natural History Museum of Kansas University have been studied, and these are designated by KU.

It is of considerable interest that all the species here described, except possibly *olivaceus,* are quite small. That such a number of them should have escaped previous collectors is possibly due to their small size, while in some cases it seems certain that the species have been relegated to described forms due to certain conspicuous or in some cases even striking similarities in scalation or coloration.

A character which has been emphasized in the identification of these species, yet which has in the past received but little attention, is the arrangement of the scales in the nasal region. Although the scales in the internasal region may sometimes vary considerably, the nasals themselves and the scales which contact the rostral are subject to but very little variation. There are three types represented in the species discussed. In one type the nasals and one or two pairs of large internasals contact the rostral. In this type the internasals are quite constant. In the second type a series of small, more or less square scales separate the internasals and nasals from the rostral. In this type the internasals may be variable. In the third type there are from two to four narrow scales quite different in character from the series in the second type, contacting the rostral and separating the nasals and internasals from it. These different types are discussed in more detail under each species.

Sceloporus parvus sp. nov.

(Figs. 1, 3 and 10; Table 1)

HOLOTYPE. Male, No. 279. Collected on June 8, 1932, in the hills about five miles west of Sabinas Hidalgo, Nuevo León, Mexico, by Edward H. Taylor and Hobart M. Smith.

PARATYPES. Five males and four females (Nos. 277, 278, 280-286) collected with the holotype; two males and one female (Nos. 4054-4056) collected 30 miles north of Matehuala, San Luis Potosi, on August 20, 1932, by the same collectors.

DIAGNOSIS. A very small *Sceloporus,* maximum body length, 50 mm.; head shields smooth, frontal variable, sometimes broken up into several small scales, always transversely divided, the anterior section frequently longitudinally divided; a small skin fold behind insertion of hind leg; dorsal scales 58 to 62 from occipital to base of tail, in parallel series; lateral scales squamous, imbricate, smaller than and gradually passing into dorsals; latter moderately

keeled, mucronate; ventrals smooth; 63 to 69 scales about middle of body; femoral pores 12 to 15, passing onto body in front of anus, separated medially by four or five scales; length of 4th toe from base of 5th approximately equal to distance from snout to middle of gular fold.

DESCRIPTION OF HOLOTYPE. Head shields smooth; six strongly keeled, imbricated superciliaries; two canthals; two series of loreals; a series of about nine flattened scales in contact with upper labials, passing from rostal to below middle of eye; five upper labials; six lower labials; four or five enlarged supraoculars; anterior third of supraocular area occupied by small scales; two series of small scales between supraoculars and superciliaries; a single row of small scales between supraoculars and frontal scales; three small parietals on each side; frontoparietals separated from each other by two small shields; a series of four small scales bordering rostral above, between nasals; two pairs of internasals, the anterior much smaller than, and separated from each other by, the posterior, which contact the small scales bordering the rostral; mental about half as broad as rostral; a series of about five enlarged, postmental scales on each side, separated from lower labials anteriorly by a single row of small elongate scales, posteriorly by two rows; a series of about five pointed scales extending over tympanum from its upper anterior border, the longest scale equaling about half the longitudinal diameter of the tympanum; a deep fold of skin between ear and foreleg; scales between ear and lateral cervical fold very small, those in a median longitudinal area somewhat enlarged and keeled, on a slight dermal ridge; all ventral scales smooth except those on tail, feet and forearm; scales above and behind insertion of foreleg granular; upper lateral scales keeled and passing gradually into dorsals; median laterals small, keeled; lower laterals smooth, larger than ventrals; scales on posterior aspect of femora granular; dorsal scales on limbs about as large as those on back, keeled; a moderately deep skin fold behind insertions of hind legs; a pair of enlarged postanals; dorsal caudals somewhat larger than dorsals on body, more strongly keeled and mucronate; ventral scales on base of tail behind anus smooth.

Head light gray, with three narrow transverse bands in supraocular region; a light line passing from posterior labial region to, and slightly beyond, ear, bordered above by a narrow black line; a dorsolateral light line on each side of body, narrow and slightly pinkish in color above foreleg, broader and bright blue posteriorly, fading out at base of tail; a bright, pinkish white line from axilla to dorsolateral line, bordered anteriorly and posteriorly by a deep black blotch; posterior black spot followed by another, less distinct, incomplete, narrow light line; a series of about six more complete transverse lines from dorsolateral line, bluish in color, whitish and broader in median lateral region, and breaking up into smaller spots and reticulations in lower lateral region, here becoming slightly bluish; lateral blotches below dorsolateral line black; a brownish black line on each side extending from occipital region to above foreleg, replaced posteriorly to base of tail by a series of eight more or less undulating cross-bars, separated medially and bordered posteriorly by light blue; tail with 13 or more undulatory brownish cross-bars; limbs dark, indistinctly banded with bluish, except tibiæ, which are strongly banded; belly on each side blue, a narrow median line somewhat lighter; breast whitish; gular region whitish, the posterior part coarsely reticulated

with black, the anterior part coarsely reticulated with blue; femora light, somewhat pinkish or orange; sides of tail blue, white medially.

VARIATIONS. The three specimens from the state of San Luis Potosi differ from the others in the following respects. The dorsals from occiput to base of tail vary in number from 67 to 74, compared with a variation of from 58 to 63 in the remainder of the series. In one male the dorsolateral dark lines beginning in the occipital region extend the full length of the body, replacing the undulating crossbars almost completely, these being only very dimly indicated.

Otherwise, both in coloration and in scale characters, these three specimens are very similar to those from Nuevo León. A larger series of specimens from the region about Matehuala may prove that the southern form is at least subspecifically distinct from the northern, but for the present the specimens available may be considered as variants.

The frontal is broken up into small scales only in the holotype; in seven others it is merely divided transversely; in the remaining four the anterior frontal is divided longitudinally; the small scales between the frontoparietals are absent in all but the type; in one the anterior parietal is fused on each side with the occipital. The scales in the nasal region are the same in all the paratypes as in the holotype. The ventral scales on the base of the tail behind the anus in females are strongly keeled; in males they are smooth. The lateral markings vary considerably. The type is the most brilliantly colored of the series. Most constant in the pattern is the bright, perpendicular light line from the axilla, and the deep black area on each side of it. The lateral blotches are dim in some specimens, especially the females; the dorsal cross-bars are constant; in males much of the light color over the body is blue; only in one female is any blue evident; the venter in females is light, only very dimly reticulated with blue in the gular region.

HABITS. All the specimens from Nuevo León were found running about on the ground among leaves and rocks in the ravines in the foothills of the mountains. They were so unwary that practically all were caught by hand.

The specimens from north of Matehuala were found in a semiarid region. They were seen on the ground near yuccas, into which they would dash when alarmed. It was only with much difficulty that the three specimens were captured, as it was necessary to tear the yuccas almost completely to pieces before the lizards would leave them.

RELATIONSHIPS. *Parvus* is apparently a member of the *variabilis* group, which also includes *couchii*. It is probably more closely related to the latter than to any other species. All three have a fold of skin back of the insertion of the hind legs, the dorsal scales are small, and the laterals are smaller than the dorsals. From *variabilis* (and its subspecies), *parvus* differs in possessing smooth cephalic scales, a larger number of rows of enlarged dorsals, femoral pores more closely approximated on the median line, a different coloration, etc. From *couchii* it differs in having a smaller number of dorsals between occipital and base of tail, squamous laterals, femoral pores more closely approximated, smaller size, a different coloration, and keels on the scales on the base of the tail behind the anus in females.

Sceloporus utiformis Cope (1864, p. 177) apparently has certain affinities to

TABLE 1. Measurements (in mm.) and scale counts of *Sceloporus parvus* sp. nov.

Number	278	4054	281	4056	4055	282	284	279	283	280	277	285	286
Snout to vent	21.5	36.5	37.5	39.0	40.0	40.0	41.0	42.0	42.5	43.0	44.5	46.0	46.0
Tail	....	....	....	....	....	....	66.5	89.0	89.5	70.0	....	....	71.0
Snout to occiput	6.5	8.5	9.25	8.5	9.0	9.5	8.75	8.5	9.5	8.75	9.0	9.5	9.0
Snout to ear	7.5	10.5	10.75	10.0	11.0	11.5	10.25	11.0	11.0	10.5	11.0	11.5	11.5
Fourth toe	8.5	13.0	14.5	12.0	14.0	14.5	12.5	14.0	14.5	13.0	13.5	13.5	13.5
Fifth toe	3.5	5.5	5.75	5.25	6.0	6.0	5.25	6.0	5.5	5.75	5.75	5.5	5.5
Tibia	6.5	9.0	10.5	9.0	9.5	10.5	10.25	10.5	11.0	10.5	10.5	10.5	10.25
Dorsals	60	67	58	74	72	61	62	62	60	62	58	63	60
Scales about body	64	....	66	70	....	65	69	69	67	63	68	67	66
Scales to shielded part of head	19	22	19	21	21	16	15	17	16	15	16	18	16
Femoral pores	....	....	14–14	15–16	14–14	13–?	12–13	15–15	14–15	15–15	13–13	15–15	14–14
Scales between series of pores	....	....	5	4	....	....	2	5	4	5	4	3	5
Sex	fem.	male	male	fem.	male	male	fem.	male	male	fem.	male	male	fem.

parvus. In the former, however, there are but ten rows of enlarged dorsals (approximately 19 to 20 in *parvus*), and the laterals are granular (squamous in *parvus*). Boulenger (1897, p. 521) states that the head scales are keeled or striated in *utiformis;* in *parvus* they are smooth.

Sceloporus maculosus sp. nov.

(Figs. 2, 4 and 11; Table 2)

HOLOTYPE. Male, No. 4483. Collected on August 29, 1932, 14 miles northeast of Pedriceña, Durango, Mexico, by Edward H. Taylor and Hobart M. Smith.

PARATYPES. Three females and two males (Nos. 4478 to 4482) collected with the holotype; also two males (Nos. 4382, 4383) collected on August 27, 1932, 6 miles northeast of Pedriceña.

DIAGNOSIS. A small *Sceloporus,* maximum length, snout to vent, 50 mm.; head shields smooth; frontal divided; dorsals 47 to 53 from occipital to base of tail, converging posteriorly; laterals squamous, larger than ventrals, smaller than dorsals, in oblique rows; femoral pores 18 to 23 on each side, separated medially by one or two scales; males without or with but slightly enlarged postanal scutes; length of 4th toe from base of 5th about equal to distance from tip of snout to between ear and gular fold.

DESCRIPTION OF HOLOTYPE. Head shields smooth; four enlarged supraoculars; 5-6 small scales in anterior supraocular region; a single row of small scales bounding supraoculars medially; one row of small scales, with a few intercalated scales separating all except the posterior supraocular from superciliaries; frontal transversely divided; a small frontoparietal on each side, widely separated by the posterior frontal, which is in contact with the occipital; two parietals on each side, somewhat larger than frontoparietal; three canthal scales, the anterior small and separated from the two posterior by a small scale on each side; two posterior prefrontals, in contact medially, extending laterally to the granular supraoculars; three large anterior prefrontals on top of head, between posterior canthals; two frontonasals between second canthals; two pairs of internasals, the anterior small and separated by the posterior, which contact the rostral; latter contacted by nasal and two internasals on each side; five upper labials, bordered above by a row of small flat scales; a few irregular loreals; mental almost square; seven lower labials; five enlarged postmental scales, separated from lower labials anteriorly by one row of small scales, posteriorly by two; ear opening small, with four elongate scales extending over it from the anterior border, the longest scale extending almost entirely across; a deep dermal pouch between ear and foreleg; all ventral scales smooth except on feet; dorsal scales on limbs, body and tail moderately keeled; those on body strongly mucronate; scales on posterior surfaces of femora granular, those on anterior surfaces large as dorsals, smooth; scales immediately above and behind foreleg granular; scales immediately in front of and above insertion of hind leg small, squamous, smooth; dorsal scales of tibiæ as large as dorsals on body; dorsal scales of femora smaller than those of tibiæ, about as large as body ventrals; dorsals of humeri slightly smaller than those on body; dorsals on lower forearm about as large as body ventrals; a small dermal fold behind the insertion of the hind leg; laterals keeled, nearly as large as dorsals, larger than ventrals, which

are smooth; laterals in oblique rows, passing dorsally; lamellæ under free part of toes one to five are 9, 12, 18, 20, 15, respectively; no enlarged postanal scales.

Above, light blue, with about nine or ten indistinct, transverse blackish bands across back, dividing into more numerous bands on sides, excluding much of the lighter color; a few whitish spots scattered over limbs, sides and back; a broad blue patch on either side of belly, extending from axilla to groin and each bordered medially by a darker blue band, almost in contact on the median line; anterior ventral surfaces of femora coarsely reticulated with very dark blue; posterior ventral surfaces of femora and preanal region whitish; otherwise, ventral surfaces of limbs and of tail light blue; a few black streaks on breast extending from in front of insertion of foreleg; posterior part of gular region whitish, with blackish encroaching from the sides along the fold; anterior part of gular region light blue, with diagonal bands of whitish passing from lower labial region posteriorly toward the median line; three black bands on anterior aspect of humerus; a rounded white spot on sides of neck immediately in front of insertion of the foreleg, bounded above and on each side by black, which extends dorsally to the dorsolateral region.

Variations. The arrangement of the dorsal cephalic scales is surprisingly uniform. In one the frontoparietals are in contact; in three they are separated by a narrow extension posteriorly of the posterior frontal; in the remaining three they are separated by a small azygos shield. Aside from a few obvious fusions of scales, four of the seven paratypes correspond almost exactly to the type in arrangement of the scales anterior to the frontal. In one of the three exceptions, the anterior pair of internasals are separated only very narrowly from each other by a posterior extension of the rostal, contacting the posterior internasals, and are nearly as large as the latter; in another, a small azygos shield is present between the two posterior prefrontals; in the other, the two posterior prefrontals have fused with the median anterior prefrontal and formed an abnormal, diagonal suture between them.

The character of the nasal shields, aside from the exception noted above, is the same in the entire series.

The females are almost uniform bluish or brownish above, with very faint indications of the dorsal bands; the ventral surfaces are whitish or slightly tinged with bluish; the anterior part of the gular region is marked as in the males, but less prominently.

In some males the dorsal bands are rather indistinct; one specimen is as inconspicuously colored as the females; in the other three the scattered whitish spots are prominent. In none are the dark blue bands on either side of the belly so closely approximated as in the holotype, but in no case are they more than two or three scale rows apart at the closest approximation.

Relationships. These lizards have a very striking superficial resemblance to *Sceloporus merriami*, yet the two species have no direct relationship. *Maculosus* differs obviously from *merriami* in the possession of squamous laterals, absence of conspicuously enlarged postanal scales in males, a smaller size, presence of a dermal fold behind the insertion of the hind leg, a smaller number of lamellæ under the free part of the 4th toe (maximum 30, minimum 24, average 26.5, in 10 *merriami*), and a different arrangement of the cephalic plates. It may be noted that the arrangement of the head scales is relatively constant

also in *merriami*. Actually closely related forms, however, are difficult to point out.

HABITS. The eight specimens were collected in a semiarid region, running about on rocks in low, almost barren hills. They were extremely wary, but could occasionally be caught alive from under rocks where they would seek shelter upon approach. Their bluish, more or less speckled coloration blended well with the color of the limestone rocks upon which they lived.

TABLE 2. Measurements (in mm.) and scale counts of *Sceloporus maculosus* sp. nov.

Number	4382	4383	4478	4482	4479	4481	4483	4480
Snout to vent	36.0	39.0	30.0	41.0	41.5	41.5	43.5	45.5
Tail	......	......	......	......	62.0	......	......	......
Snout to occiput	9.0	8.25	9.0	9.25	8.5	8.5	9.0	9.0
Snout to ear	11.0	11.0	10.5	10.5	10.5	10.5	11.5	11.25
Fourth toe	12.0	11.0	11.5	12.5	11.0	12.0	12.0	13.0
Fifth toe	6.0	5.5	6.0	6.0	6.0	6.0	6.0	6.5
Tibia	10.0	9.5	9.0	10.0	9.5	10.0	10.5	10.0
Dorsals	47?	52	49	49	48	52	49	53
Scales about body	51	53	54	52	54	49	50	58
Scales to shielded part of head	14	13	14	12	12	12	12	13
Femoral pores	21–23	18–?	19–19	20–20	19–19	19–19	20–20	22–?
Scales between series of pores	2	2	2	1–2	2	1	1	2
Sex	male	male	fem.	male	fem.	fem.	male	male

Sceloporus ochoterenæ sp. nov.

(FIGS. 6, 9 and 12; Table 3)

HOLOTYPE. Male, No. 1075, collected two miles north of Mazatlán (12 miles south of Chilpancingo), Guerrero, Mexico, on June 26, 1932, by Edward H. Taylor and Hobart M. Smith.

PARATYPES: Forty-seven, including twenty-five (Nos. 1066, 1068 to 1074, 1077 to 1085, 1087 to 1095) collected with the holotype, and 3 (Nos. 1548 to 1550) collected at the same place, on July 2; 12 (Nos. 676, 722 to 731, 775) collected 11 miles southwest of Puente de Ixtla, Guerrero, on June 22 and 23; 2 (Nos. 782, 783) collected near Acuitlapan, Guerrero, on June 23; 2 (Nos. 840, 970) collected near the junction of Río Balsas and the Mexico-Acapulco highway, on June 23 and 24; 1 (No. 1552) collected between Cajones and Acahuitzotla, Guerrero, on July 2; and 1 (No. 1653) collected 5 miles south of Puente de Ixtla, Morelos, on July 4; all collected by Taylor and Smith.

DIAGNOSIS: A small *Sceloporus*, maximum length, snout to vent, about 55 mm.; frontal transversely divided, the anterior section sometimes longitudinally divided; posterior section of frontal separated from occipital by two large, contiguous frontoparietals; head shields rugose or keeled; frontal ridges absent or inconspicuous; two canthals; nasals and two large internasals con-

tacting rostral; three or four large scales on anterior border of ear, not so large as in *jalapæ,* the median not greatly enlarged; scales between ear and lateral cervical fold larger than scales on throat; dorsal scales 38 to 46 from occiput to base of tail, strongly keeled and mucronate, in longitudinal series slightly diverging posteriorly; laterals keeled, in oblique rows directed upward, much smaller than and usually gradually merging with dorsals, slightly smaller than ventrals; latter smooth, with a single apical notch; femoral pores, 11 to 15 on each side, the two series separated on the median-ventral line by three or four scales; ventral scales in front of anus and on base of tail keeled in females; dorsal caudals but slightly larger than dorsals on body; tibia longer than shielded portion of head; length of 4th toe from base of 5th about equal to distance from snout to lateral neck folds.

DESCRIPTION OF HOLOTYPE. Head shields weakly striated; frontal ridges weak; frontal transversely divided, the anterior section about four times as large as the posterior; two frontoparietals, about the same size as the posterior frontal, in contact with each other behind frontal, separating the latter from the occipital and parietals; three or four parietals on each side, the posterior three or four times as large as any of the others; occipital very large, more or less rounded in outline; four large supraoculars, bounded inwardly by one series of small scales, outwardly by one to three rows, increasing anteriorly; two canthals, much broader than long; two large internasals contacting the nasals on the sides, and followed posteriorly by another pair of scales equally as large; nasals and internasals contacting rostral; one to two series of small, flattened, weakly keeled scales bordering upper labials above; three large suboculars, the median much the longest, followed anteriorly by a subocular which contacts the loreal and anterior canthal; five upper and six to seven lower labials, weakly keeled; mental pentagonal, about one-third as broad as rostral; a series of three enlarged postmentals on each side, the anterior pair in contact with each other and with the first lower labial; temporal scales somewhat smaller than those on throat, keeled; three to four smooth scales on anterior border of ear, as large as or larger than those preceding them, one of them one-half to two-thirds larger than the others; lateral cervical fold shallow; a weak gular fold; no indication of a second gular fold; scales between neck fold and ear larger than throat scales, keeled; scales between lateral fold and insertion of foreleg as large as ventral abdominals; scales above insertion of foreleg granular; scales in axilla smooth and squamous; median and upper laterals keeled; smallest laterals smaller than ventral abdominals, much smaller than dorsals; laterals gradually merging with dorsals and ventrals; scales in front of groin about half as large as laterals, keeled, quinquedentate; ventrals smooth, notched at tip; scales above insertion of hind leg squamous, those behind granular; no dermal fold behind insertion of hind leg; ventral scales on femora smooth and about equal in size to ventral abdominals, those on tibiæ smooth and larger; dorsals on hind limbs keeled, all about equal in size, those on tibiæ perhaps somewhat larger; posterior femorals quite small, squamous, keeled, encroaching but little on the dorsal surface; dorsals on foreleg about equal in size to smallest laterals, those on humerus perhaps somewhat larger; ventrals on lower foreleg larger than ventrals on humerus, those on posterior portion keeled; anterior ventrals of humerus keeled; ventrals in front of anus and on base of tail smooth;

postanals enlarged; dorsal caudals about equal in size to dorsals on body, or somewhat larger; lamellæ under free parts of 1st to the 5th toes 8, 14, 17, 24, 15, respectively.

Head light grayish-blue; a black spot on shoulder; a bright, narrow black line from posterior margin of orbit to upper edge of tympanum, continued posteriorly onto sides of tail as a broad band, and breaking up into a series of large black spots on the sides between fore and hind legs; these spots bordered above by a light blue line, broad and of indefinite outline posteriorly, narrow and distinct above forelegs; a broad median bluish band, darker than lateral light bands bordering it; a series of about 11 small black spots on each side near the edge of the median dorsal band; limbs grayish, banded with black; tail light bluish; sides of abdomen on venter bluish, darker toward median edges, with some suffusion of pinkish; sides of body below lateral dark spots and above blue on sides of abdomen, greenish blue, more or less iridescent, stippled with black; chest and ventral surfaces of limbs white; tail very light lavender below; throat, in posterior region, moderately dark blue; chin whitish.

VARIATIONS. The scales in the prefrontal region are quite variable, and even the frontal is variable, being broken up into several small scales in some and the anterior section longitudinally divided in others. The relative proportion of the anterior and posterior sections of the frontal thus varies considerably, as does also the relative proportion of the posterior parietal, although the latter scale is always much the largest of the parietals. However, the arrangement of the internasal scutes is the same in all; the frontal is always separated from the occipital and parietals by two frontoparietals; two canthals are always present. The rugosity of the cephalic plates varies considerably, but the small scales in the supraorbital region are always keeled, however nearly smooth the other scales are. The frontal ridges are usually not visible, but occasionally are very dimly indicated.

The males vary but little in coloration from the above description. In some the whole body is quite rusty in appearance, and the markings are very dim, if evident at all. Usually the small black marks on the edge of the median band are rather dim. The limbs are frequently very strongly banded with black and whitish, and in other specimens the bands are dim. The lateral dark spots are evident in all except a few extremely dark males.

The color pattern of females in no way resembles that of the males. The whole dorsal surface is of a brownish hue, lighter on the head. There is a series of eleven or twelve rather broad undulating cross-bars on each side of the back, the series on each side separated by three or four scale rows. If the lateral light line below the cross-bars is visible at all, it is only above the forearm; it fades out almost entirely before reaching the sacral region. In some specimens the sides of the body are dark, in others they are grayish, but no spots are apparent. The shoulder mark is absent. The limbs are, as in males, distinctly banded in some, in others, not. The venter is whitish, sometimes with a bluish suffusion; the lower labial and lateral gular region may be diagonally banded.

In all females the ventral scales in front of the anus and those on the base of the tail are keeled; in males they are smooth.

RELATIONSHIPS. The females of *ochoterenæ* have a striking resemblance to *æneus*, even to a greater extent than the females of *jalapæ*. The relationship of the two, however, is not close. It differs from *æneus* in the less rugose head shields, great reduction of the frontal ridges, much different character of the nasal and internasal shields (these always separated from the rostral by a series of from two to four small, flat scales in *æneus* and *scalaris*), in the presence of two frontoparietals between the frontal and occipital, the obliquely directed rows of laterals, longer hind limbs, longer 4th toe, squamous posterior femorals, larger size, different coloration in the males, and numerous other characters.

Ochoterenæ is more closely related to *jalapæ* than to any other species, apparently. From the latter it differs in the smaller number of dorsals, larger scales in the temporal region and between the ear and the lateral cervical fold, squamous posterior femorals, smaller number of femoral pores, keeled scales in front of anus and on base of tail in females, and much smaller scales on anterior border of ear. The lateral dark band is not broken up into large spots in the males of *jalapæ*, and the limbs are less distinctly banded.

Ochoterenæ differs from *grammicus* in the possession of a pair of frontoparietals separating the frontal from the occipital, larger scales on the anterior border of the ear, longer 4th toe, caudals about equal in size to dorsals on body, different coloration, etc.

REMARKS. It is inconceivable that a species so common in Guerrero, where Gadow and others collected extensively, should not have been collected. It is, on the other hand, quite likely that the specimens obtained have been considered as *æneus* or *scalaris*, due to certain rather striking superficial resemblances, especially of the females, to one or the other of those species.

The specimens collected north of Mazatlán were all found running about in leaves in ravines. The temperature was rather low and the sky cloudy, so it is possible that they were more restricted in their movements than usual. However this may be, all were taken on the ground, frequently by raking away piles of wind-accumulated leaves. The brownish color of the females and the darker color of some of the males well concealed them among the similarly colored leaves.

This species is named for Dr. Isaac Ochoterena, director of the Instituto de Biología of the Universidad Nacional de Mexico in Mexico City, in recognition of the numerous courtesies extended to Doctor Taylor and myself during our sojourn in Mexico.

Sceloporus megalepidurus sp. nov.

(Figs. 7, 8 and 18; Table 4.)

Sceloporus consobrinus Boulenger 1885, pp. 229, 230 (*part*).
Sceloporus consobrinus Gunther 1890, pp. 69, 70 (*part*).
Sceloporus consobrinus Boulenger 1897, pp. 486-488 (*part*).

The above synonymy concerns a certain specimen in the British Museum, collected at Putla, Puebla, and obtained from Boucard. That this specimen is the same as *megalepidurus* cannot be stated positively, because of the fact that all descriptions concerned, of *consobrinus*, are composites. There are certain similarities, however, between this species and *megalepidurus*. It is also quite unlikely that *consobrinus* exists in Puebla and southern Vera Cruz, where

TABLE 3. Measurements and scale counts of *Sceloporus ochoterenæ* sp. nov.

Number	724	1077	1084	1085	1653	1549	1091	676	729	1070	1072	1083	1075
Snout to vent	42.0	42.5	44.0	44.0	44.5	45.5	46.0	49.0	50.0	50.0	51.0	52.5	53.5
Tail	70.0	50.0	59.0	60.0	66.0	77.0	58.0	90.0	95.0	81.5	85.0	82.0	84.0
Snout to occiput	9.5	8.75	9.25	9.0	9.0	9.5	9.0	10.0	10.5	10.0	10.0	10.5	11.0
Snout to ear	11.0	11.0	10.5	11.0	11.0	11.5	11.0	13.0	13.0	12.5	13.0	13.0	13.0
Fourth toe	12.5	12.0	11.5	11.0	11.5	12.5	11.5	15.5	16.0	14.5	15.0	15.5	15.75
Fifth toe	5.5	5.0	5.0	5.5	5.0	5.5	5.5	7.0	7.0	6.5	7.0	7.0	7.0
Tibia	10.0	9.0	9.25	9.5	9.5	10.5	9.5	12.0	12.0	10.5	11.0	12.5	12.5
Dorsals	43	43	43	44	46	38	41	41	41	43	46	44	46
Scales about body	50	47	47	46	49	48	46	47	47	51	51	49	51
Scales to shielded part of head	9	10	9	9	10	10	8	9	10	9	9	9	10
Femoral pores	14–15	11–13	13–13	12–13	14–14	13–13	13–13	13–14	13–13	12–13	14–15	14–14	13–15
Scales between series of pores	4	3	3	4	3	3	3	4	3	4	3	4	4
Sex	fem.	fem.	fem.	fem.	fem.	male	fem.	male	male	male	male	male	male

megalepidurus occurs. From these facts it appears probable that the specimen from Putla is identical with *megalepidurus*.

HOLOTYPE. Female, No. 2908, collected near Totalco, Vera Cruz, Mexico, on July 19, 1932, by Edward H. Taylor and Hobart M. Smith.

PARATYPES. Sixty-three, including 21 (Nos. 2907, 2909, 2910, 2912-2920, 2922-2931) collected with the holotype; 10 (Nos. 1798, 1800-1806, 1808-1809) collected near Tepeyahualco (about 19 miles west of Perote), Puebla, on July 12; 32 (Nos. 1863-1872, 1874-1895) collected 15 miles east of San Marcos (about 55 miles east of Perote), Vera Cruz, on July 12; all collected by Taylor and Smith.

DIAGNOSIS. A small *Sceloporus*, maximum snout to vent measurement about 55 mm.; head shields smooth; one canthal; frontal transversely divided, separated from occipital by a pair of interparietals or a small azygos shield; a row of small scales about inner border of enlarged supraoculars; tibia as long as or slightly longer than shielded portion of head; length of 4th toe from base of 5th equal to or slightly greater than distance from snout to posterior border of ear; dorsal scales moderately keeled, slightly mucronate; laterals in oblique series; scales about body nearly equal in size; dorsals 56 to 61; scales about body less than dorsals from occiput to base of tail; caudals two or three times as large as scales on body; no lateral abdominal marks in males.

DESCRIPTION OF HOLOTYPE. Cephalic scales smooth; dorsal scales on head, sides of neck and labial region pitted about edges; frontal transversely divided, posterior section about three-fourths smaller than anterior; two contiguous frontoparietals separating frontal from occipital; three parietals on each side, the median about twice as large as either of the others; four or five enlarged supraoculars, bordered on inner edges by a series of small scales; a series of scales on outer edge of above row of supraoculars, about one-third as large as these, and separated from superciliaries by one to two rows of small scales; anterior fourth or fifth of supraorbital area filled with small scales; seven large scales in prefrontal area, grouped about a large median scale; two large internasals, separated from rostral by one row of small, squarish scales; one canthal; anterior subocular and loreal contacting canthal scale; an elongate scale immediately below nasal, contacting loreal and canthal; a series of one to two rows of scales above upper labials; one row of scales, with four between the nasals, continued around snout above rostral, separating the latter from the nasals and internasals; five upper and eight lower labials, a few of the posterior scales keeled, all pitted; rostral very low, about one-half broader in middle than at lateral edges; mental pentagonal; a series of three or four enlarged postmentals, separated from lower labials by one to two rows of scales; anterior postmentals in contact on median line; temporal scales keeled; three large, smooth scales on anterior border of ear, the upper the largest and extending almost entirely across tympanum; scales between ear and lateral cervical fold almost as large as dorsals, even more strongly keeled; scales in axilla granular, those immediately behind axilla squamous, smooth and deeply notched at tip; laterals and ventrals about equal in size, slightly smaller than dorsals; lower laterals smooth, deeply notched; upper laterals strongly keeled, strongly mucronate, tridentate; dorsals not so strongly keeled and mucronate as upper laterals, some tridentate; most of ventrals notched at tip; ventrals in gular region slightly smaller than

those preceding and following them; scales in groin squamous, smooth, entire, those above insertion of hind leg smaller; scales behind insertion of hind leg granular; no dermal fold behind insertion of hind leg; dorsals on tibia and femur strongly keeled, tridentate, somewhat larger than those on body, those on tibia largest; postfemorals distinctly squamous, smooth or weekly keeled, smaller than scales in front of anus; ventrals on femur immediately preceding femoral pores about the size of those in front of anus, or slightly smaller; dorsals on forelimb of about equal size and of about the same size as the dorsals on body, moderately keeled; ventrals on forelimb smaller than ventrals on breast, smallest on humerus; scales in front of and behind anus smooth; caudal scales strongly keeled, mucronate, tridentate, and two to three times as large as dorsals on body; lamellæ on toes 1 to 5 are 11, 15, 19, 21, 15, respectively.

Color above approximately seal brown; a series of about 12 or 13 small, black spots of indefinite outline on each side of median dorsal line from neck region to base of tail, each spot bordered behind by an indefinitely outlined small light spot; sides clove brown, becoming very light, dirty pale blue on venter; a moderately distinct light-brown stripe from axilla to groin; a light-brown streak separating the dark sides from the lighter dorsum, more distinct and narrowly confined in the region above insertion of foreleg; a distinct, dirty white stripe from the lower ocular region through ear to above insertion of foreleg, there uniting with a dim vertical stripe from insertion of foreleg to the dorsolateral light line; venter entirely uniform, very light, dirty pale blue.

VARIATION. A character emphasized in the separation of this species from certain others is the possession of but one canthal scale. Since certain authors have placed doubt upon the stability of the character of the canthal scales in certain species, it is worthy to mention that in the entire series of 63 of this species, there is but one canthal on each side in each specimen.

The parietal scales are quite variable, but the general plan seems to be the same as in the holotype.

The frontal is about as frequently in contact with the occipital as it is separated from it by the frontoparietals or the small azygos scale. The pits on the scales are very conspicuous in all specimens, especially in the prefrontal region. The ear scales are present and large in all.

The males of this species resemble very closely the females. The venter is uniform, as in the other sex. However, the postanal scales are enlarged and the femoral pores are much more distinct.

RELATIONSHIPS. The relationship of this species is quite possibly to the *microlepidotus* group, although it cannot be close. They agree in the large size of the caudals, compared with the dorsals on the body. *Megalepidurus* differs from that group, however, in having larger dorsal scales, more uniform scales about the body, one canthal, and the frontal frequently separated from the occipital, never in broad contact.

It differs from *ochoterenæ* and related species in the same characters mentioned above, and in the smaller number of femoral pores, the series more widely separated in the median ventral line, and in the smooth cephalic scales

From *consobrinus* and *graciosus* this species differs markedly in possessing

TABLE 4. Measurements and scale counts of *Sceloporus megalepidurus* sp. nov.

Number	1808	1803	1806	1863	1878	1800	1882	1883	1892	1877	2908
Snout to vent	45.0	46.5	47.5	48.0	48.0	49.5	50.5	51.0	53.0	53.5	44.0
Tail	66.0	63.0	57.5	62.5	73.0	55.0	68.0	64.5	70.0	61.0	60.5
Snout to occiput	9.5	9.0	10.0	9.5	10.0	10.0	10.5	10.25	10.75	10.0	9.0
Snout to ear	11.0	10.75	11.5	11.0	12.0	12.5	12.5	12.5	13.0	12.5	11.0
Fourth toe	12.5	12.0	14.0	12.0	14.0	14.5	13.5	13.5	14.5	14.25	11.75
Fifth toe	6.0	5.5	6.5	6.0	6.5	7.0	6.5	6.5	7.0	7.0	6.0
Tibia	9.0	9.0	11.5	9.0	10.0	10.0	11.0	10.5	11.0	11.0	8.5
Dorsals	56	59	57	60	59	57	56	57	61	59	59
Scales about body	49	51	49	52	54	54	53	54	53	50	52
Scales to shielded part of head	13	13	13	12	14	14	14	12	14	13	12
Femoral pores	15–16	16–16	16–17	15–15	16–17	17–17	15–15	15–16	15–16	13–16	16–16
Scales between series of pores	6	6	5	6	6	4	5	6	6	4	7
Sex	fem.	fem.	male	fem.	male	male	male	male	male	male	fem.

relatively very large caudal scales, smaller supraorbitals, one canthal, scales practically uniform in size about the body, etc.

HABITS. These lizards were collected in rather high, semiarid regions near the eastern edge of the Mexican plateau. They were largely confined to the ground on hills and lava beds, apparently not living in the plains. They were frequently found under fallen yuccas.

Sceloporus olivaceus sp. nov.

(Table 5)

HOLOTYPE. Male, No. 2508, in the collection of Edward H. Taylor. Collected by Edward H. Taylor and John S. Wright in a mesquite tree near the lower end of Arroyo Los Olmos, about 3 miles southeast of Rio Grande City, Texas, August 23, 1931.

DIAGNOSIS. A *Sceloporus* with smooth cephalic scales; frontal transversely divided; tail rounded; general form slender; dorsals 32 from occiput to base of tail; scales about middle of body 34; seven scales in middle of back correspond to length of head from snout to occiput; length of 4th toe from base of 5th equals the distance from snout to shoulder; length of tibiæ slightly greater than length of shielded part of head; difference between the latter and length of 5th toe less than one-fourth of the latter; eleven or twelve anal pores; nares large, closely approximated, situated in a depression; color uniform olive above, whitish below.

DESCRIPTION OF HOLOTYPE. Head shields smooth; frontal transversely divided; about 5 enlarged supraoculars, bounded medially by one complete row of small scales, separated from superciliaries by one to two rows of small scales; at least one large parietal on each side, about two-thirds as large as occipital, extending as far posteriorly as occipital and closely contiguous with the latter for its entire length; anterior section of frontal as long as broad, much narrowed posteriorly; five prefrontals, in two series, the posterior with two scales, the anterior with three; two comparatively small canthals; the anterior part of the anterior superciliary forming a part of the canthal series, separated by one small scale from the three anterior prefrontals; canthals contacting the lateral scales of the series of three anterior prefrontals; two rather small frontonasals, separated from the anterior canthals by the lateral scales of the series of three anterior prefrontals, which contact two or three small scales back of nares; two pairs of internasals, the anterior quite small; internasals separated by two small scales from nares; rostral low, about three times as broad as high; five very low upper labials, separated from the elongate, keeled subocular by one to two rows of small, elongate scales; two loreal scales, the anterior bordering the nares below; seven lower labials, separated from the series of enlarged submentals by two rows of elongate scales; temporal scales keeled; ear opening diagonal, bordered in front by a series of four or five projecting scales of about the same size as or slightly smaller than those immediately preceding them; a deep, diagonal pouch on either side of neck between ear and forearm, bordered anteriorly by about four keeled, projecting scales, larger than those preceding them; laterals rather strongly keeled, larger than ventrals, smaller than dorsals, in oblique rows; ventrals smooth; scales in axilla granular; scales immediately above and

behind axilla small, squamous, smooth; laterals and dorsals continuous to insertions of hind legs; scales behind insertions of hind legs almost granular, very small, smooth; dorsal scales on limbs about as large as smallest laterals, keeled; those on tibiæ not enlarged; ventral scales on limbs smooth, except on humeri and tibiæ; scales on tail strongly keeled and mucronate, about as large as or slightly smaller than dorsals; postanals enlarged.

TABLE 5.—Measurements (in mm.) and scale counts

	S. olivaceus.	*spinosus floridanus.*						
Number	2508	15316	15032	15042	15045	15033	15040	222
Snout to vent	57.5	56.5	59.0	59.0	59.5	60.0	63.5	65.0
Tail	86.5	....	104.0	105.0	....	99.0	104.0	110.0
Snout to occiput	11.25	12.0	12.5	13.0	13.0	12.5	13.0	13.75
Snout to ear	15.0	14.5	16.5	16.25	16.0	15.5	16.5	17.0
Fourth toe	20.0	17.0	18.5	19.5	19.5	19.0	21.0	21.0
Fifth toe	9.0	7.0	8.0	9.0	9.5	8.5	9.0	8.5
Tibia	12.0	11.5	12.0	12.5	12.5	12.5	13.5	13.0
Dorsals	32	29	29	29	29	28	31	31
Scales about body	34	32	34	35	34	30	37	35
Scales to shielded part of head	7	6	6.5	6	6	6	5.75	6
Femoral pores	11–12	12–13	15–?	11–13	12–12	12–13	14–14	15–14
Hind limb	47.0	42.5	44.0	47.0	46.0	44.0	50.0	47.0
Fore limb	29.0	26.5	27.5	28.0	27.0	27.0	35.0	29.0
Sex	male	fem.	fem.	fem.	male	fem.	male	male

Color in life uniform bright olive above, head brownish olive; tail and limbs above similar to body; digits dimly banded with olive and grayish; a tinge of iridescent bluish between ear and shoulder, extending onto sides of throat a short distance; abdomen tinged with bluish, the latter gradually merging with a broad median whitish area; throat, chin, pregular region and ventral surfaces of femora and humeri whitish; ventral surfaces of tibiæ, lower forearm and tail tinged with bluish.

RELATIONSHIPS. This distinct species is related to *spinosus* and *asper*. It differs from *asper* in the much longer 4th toe, smaller number of femoral pores, different arrangement and shape of cephalic plates, smaller number of scales about the body, and tibiæ longer than the shielded part of the head.

Spinosus differs from *olivaceus* in a number of respects. The canthal scales are larger and wider in *spinosus,* and the anterior superciliary does not form a part of the canthal series; the nares are smaller and farther apart; the parietals do not extend as far posteriorly as the occipital; the anterior section of the frontal is much broader; the shielded part of the head is longer, and frequently much more, but never less, than one and one-half times as long as the 5th toe (one and one-fourth times in *olivaceus*); the limbs are shorter (hind limbs

4.5 mm., fore limbs 2.5 mm., shorter in a specimen of approximately the same size as the type of *olivaceus*); the body is much more robust; and the color pattern is much different, consisting of a general brownish color, with a series of darker brown spots or bands down the middle of the back, and sides dark.

REMARKS. That this species is not a variant of *spinosus* is further emphasized by the fact that it exists, as much collecting near the type locality has indicated, in an area where *spinosus floridanus* is very abundant.

Mrs. Helen T. Gaige and Dr. Leonhard Stejneger have examined the specimen, and have kindly offered their opinion with regard to its status, which concurs with that expressed here.

Table 5 gives comparisons between *olivaceus* and *spinosus floridanus*.[1]

For constant aid and advice during the course of the study of these lizards I am indebted in particular to Dr. Edward H. Taylor, who has also kindly permitted me to study and describe a specimen from his own collection. Mr. C. D. Bunker, curator of Dyche Natural History Museum of Kansas University, has very kindly loaned many specimens for examination. I am also greatly indebted to Dr. H. H. Lane for much assistance, especially with regard to photographs.

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1. No. 222 is from near Pearsall, Frio county, Texas; KU 15040, 15042, 15045, from Helotes, Bexar county, Texas; KU 15032, 15033, 15816, from Somerset, Bexar county, Texas.

EXPLANATION OF PLATES

PLATE VIII

FIG. 1. *Sceloporus parvus.* Female paratype (No. 286). Total length, 117 mm.

FIG. 2. *Sceloporus maculosus.* Female paratype (No. 4481). Total length, 79 mm.

FIG. 3. *Sceloporus parvus.* Holotype. Total length, 131 mm.

FIG. 4. *Sceloporus maculosus.* Dorsal head scales of holotype. Actual length, 11.5 mm.

FIG. 5. *Sceloporus maculosus.* Holotype. Total length, 75.5 mm.

PLATE VIII

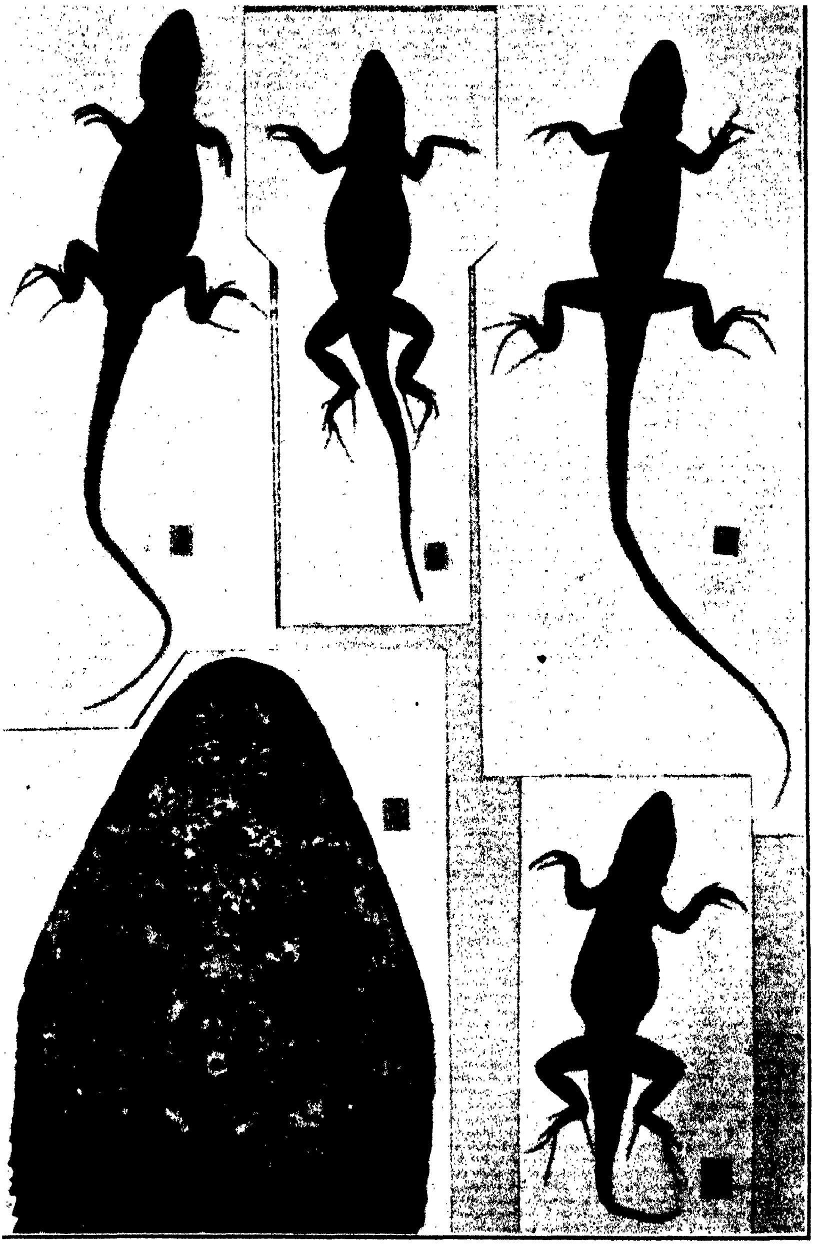


PLATE IX

FIG. 6. *Sceloporus ochoterenæ.* Holotype. Total length, 137.5 mm.

FIG. 7. *Sceloporus megalepidurus.* Male paratype (No. 2931). Total length, 101 mm.

FIG. 8. *Sceloporus megalepidurus.* Holotype. Total length, 104.5 mm.

FIG. 9. *Sceloporus ochoterenæ.* Female paratype (No. 1095). Total length, 97 mm

PLATE IX

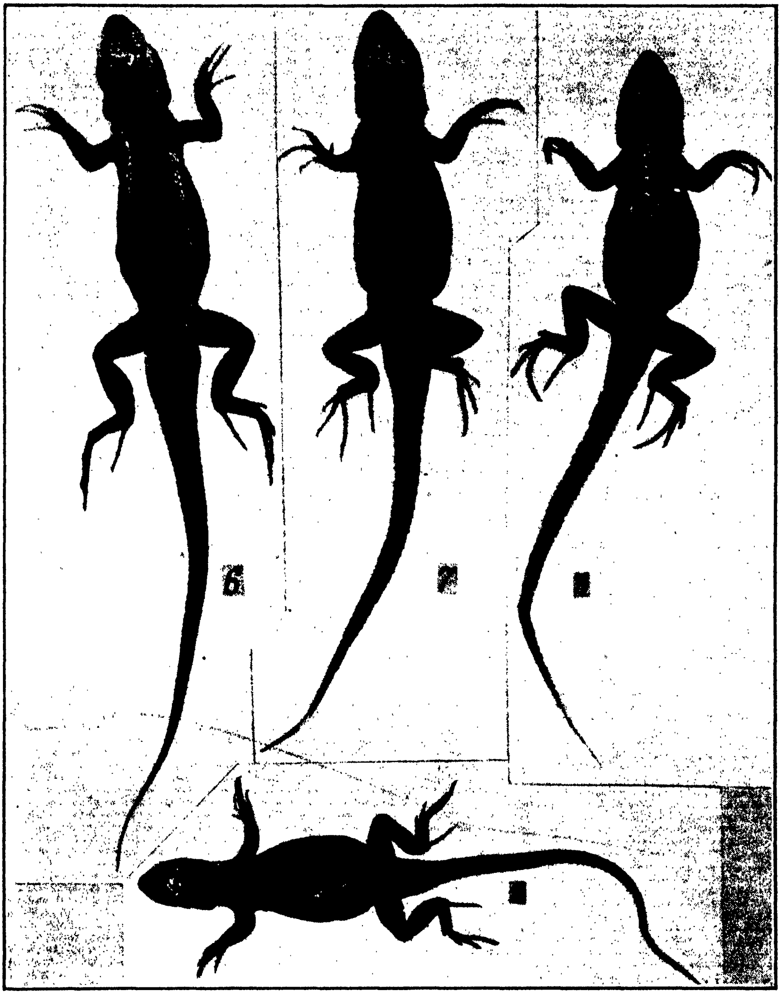


PLATE X

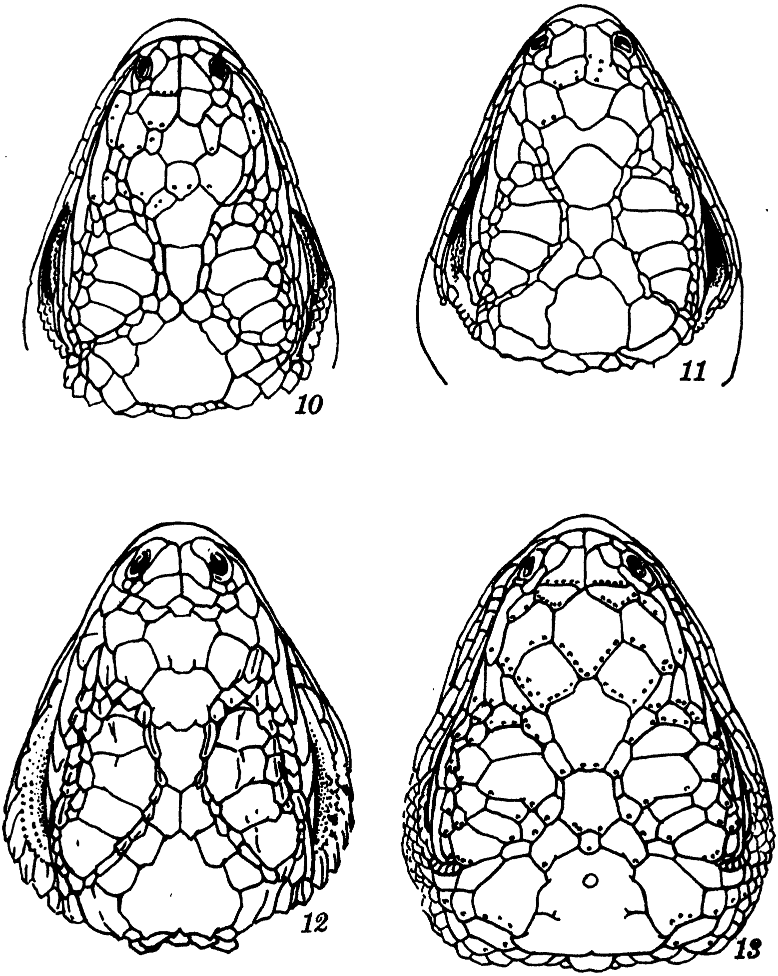
FIG. 10. *Sceloporus parvus.* Dorsal view of cephalic scales of male paratype (No. 282). Actual length of figured portion, 10 mm.

FIG. 11. *Sceloporus maculosus.* Dorsal view of cephalic scales of female paratype (No. 4481). Actual length of figured portion, 9.5 mm.

FIG. 12. *Sceloporus ochoterenæ.* Dorsal view of cephalic scales of male paratype (No. 723). Actual length of figured portion, 11 mm.

FIG. 13. *Sceloporus megalepidurus.* Dorsal view of cephalic scales of male paratype (No. 1882). Actual length of figured portion, 11.5 mm.

PLATE X



Notes on Some Lizards of the Genus *Phrynosoma* from Mexico

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(PLATES XI and XII)

Fourteen forms of horned lizards have been recorded from the mainland of Mexico. The ranges of these respective forms may be readily segregated into three divisions, namely:

1. A group composed of *douglassii hernandesi, m'callii, solare, goodei* and *ditmarsi,* the ranges of which, in Mexico, are confined to the area about the state of Sonora.
2. A plateau group, consisting of *cornutum* and *modestum,* which, in Mexico, are confined to the northern part of the Mexican plateau west of the Sierra Madre Occidental, and north of about the 23d or 24th parallel.
3. A southern group, composed of *boucardii, orbiculare* (including *cortezii* and *dugesii*), *asio, taurus* and *braconnieri.* This group is a heterogeneous composite which is somewhat puzzling, possibly due to incorrect data in certain cases. All species may be considered as inhabitants almost exclusively of the region south of about the 22d parallel. *Orbiculare* is an exception, for, although confined for the most part to the highlands on the edges of the plateau, within the areas of deciduous and pine forests, it extends also northward along the Sierra Madre Occidental at least as far as the city of Durango (Günther, 1893), and possibly into Chihuahua (Terron, 1932). The records of *orbiculare* from the United States, of Hallowell (1853) and Holbrook (1838) were (*fide* Van Denburgh [1932]) based upon specimens of *douglassii hernandesi* and *cornutum,* respectively. Cope's (1900) record from Fort Huachuca was based, as one may gather from Stejneger's (1902) report on the reptiles of the Huachuca Mountains, upon a specimen of one of the above two species.

Asio and *braconnieri* are typically inhabitants of semiarid basins of the southern part of the plateau. *Asio* also extends farther south, into Tehuantepec and Guatamala. *Taurus* may also be an inhabitant of the semiarid basins, as might be inferred from its habitus and from the meager available data. Günther's (1893) record from Matamoros very probably infers the Matamoros of the state of Puebla, not of Tamaulipas. The same author also reports a specimen from Amula in Guerrero, at 8,000 feet. This latter is hardly consistent with other data on habitats, yet, until further knowledge of habitat preferences is available, the record cannot be refuted. *Boucardii* is possibly also characteristic of the high, western-central, semiarid plateau. Dugés (1896) has recorded it definitely from León, Guanajuato.

Six species and subspecies of *Phrynosoma* were collected by Doctor Taylor and myself in various states of Mexico during the summer of 1932. The following notes are based upon the specimens in this collection (to which catalogue numbers refer).

Phrynosoma asio Cope

Four adults of moderate size (Nos. 963♀, 1584♂, 1583♂, and 1581*) were collected in the state of Guerrero, near the junction of the Rio Balsas and the Mexico-Acapulco highway, on July 2, 1932. The particular area in which these were caught is semiarid and rather hilly, with gravelly soil almost entirely free of grass, but with scattered low bushes and occasional stunted trees on hillsides.

Distributional records of this species are scanty. Terron (1932) overlooked it entirely. It has been recorded from Colima by numerous authors, from Tehuantepec (Gentry, 1885, p. 145), Guatamala (Günther, 1893, p. 79) and Lower California (Boulenger, 1885, p. 244). This latter record has not been confirmed by recent authorities on the herpetology of Lower California (Schmidt, 1922; Linsdale, 1932). Van Denburgh (1922) considers it based upon specimens of *P. coronatum* Blainville.

MEASUREMENTS AND SCALE COUNTS OF *Phrynosoma asio* Cope

Number	*1584*	*963*	*1583*
Total length	165.0	170.0	175.0
Snout to ear	18.0	19.2	20.0
Width of head	23.0	23.0	22.8
Fore limb	41.0	49.5	51.0
Hind limb	59.0	66.0	63.0
Tail	63.0	62.0	72.0
Femoral pores	8–9	9–7	7–8
Upper labials	9–8	8–8	8–9
Lower labials	11–12	13–13	11–13
Enlarged infralabials	10–10	9–9	9–10

Phrynosoma braconnieri Bocourt

One specimen (No. 3121♂) of this rare species, previously reported only from Oaxaca, was collected in the state of Puebla, 14 miles northeast of Tehuacán, on July 23, 1932. It was found in a semiarid region characterized by light, alkaline soils, with which the color pattern of *braconnieri* blends almost perfectly.

This species also is not mentioned in Terron's monograph (1932).

The specimen may be described as follows:

Head considerably wider than long; dorsal profile, as observed from the side, smoothly curving from supraorbital horn to snout; latter not truncate; temporal region extended posterolaterad, somewhat excavated; nostrils pierced within canthi, directly bordering the same or separated by one scale; nostrils separated from rostral by four scales, from each other by three; rostral low, three times as broad as long; mental slightly broader than long, narrower than rostral; all head scales, except those typically produced as horns, rugose, not spinose, save in parietal and temporal regions; supraorbital scales smaller and less rugose than frontals, smallest near superciliary ridge; supraocular scales somewhat enlarged, separated medially by a row of small scales; parietal and temporal scales larger than supraoculars, some spinose; anterior superciliary ridge separated from posterior ridge by two or three small scales; latter ridge consists of three enlarged scales, the posterior one produced as a horn, much smaller than either occipital, and yet smaller than any of the four enlarged

* This specimen was retained by the Instituto de Biologia of the Universidad Nacional in Mexico City.

temporals; upper labials continuous with enlarged temporals, about six of the latter conspicuously enlarged, the terminal four the largest; last temporal anterior to preceding, separated from the occipital horn by one or two scales; one occipital spine on each side, about twice as large as temporals, separated from each other by about five scales, the median of which is produced into a very low interoccipital horn; infralabials enlarged, about the size of lower labials, in contact with the latter except in a narrow region below orbits, where a few small scales are intercalated; gular scales small, carinate, of nearly uniform size; a strong gular fold present, lined with granular scales, terminating in an extremely deep pouch anterior to insertion of fore limbs; this pouch overhung by a dorsal fold of skin, and bordered posteriorly, above axilla, by another fold; a lobe of skin between lateral gular pouches and tympanum, bearing a number of large spines; tympanum bare; a series of enlarged lateral abdominal scales extending from in front of arm insertions to groin; three enlarged, low, keeled scales on each side of the dorsal median line on neck; large, keeled and mucronate tubercles scattered over back, tail and hind limbs, largest on either side of median line; dorsal scales otherwise granular, rugose or keeled; no enlarged scales on median dorsal line; a lateral series of enlarged scales along sides of tail at base; ventral surfaces of tibiæ and anterior surfaces of femora with imbricating, keeled scales about equal in size to ventral pectorals and abdominals, which are also keeled; scales of lower forearm enlarged and keeled; a row of similar scales on anterior aspect of humerus.

Color very light; an indistinct, dark blotch on either side of neck behind the temporal region; dorsal surfaces very faintly suffused with darker; a pinkish tinge evident in dorsolateral region and on head; belly and gular region whitish, with small, scattered dark spots.

Total length, 44.5 mm.; head width, 12.0 mm.; snout to ear, 8.8 mm.; fore limb, 19.0 mm.; hind limb, 28.0 mm.; tail, 7.5 mm.; femoral pores, 11-12; upper labials 12-13; lower labials, 12-13; enlarged infralabials, 10-10.

Phrynosoma cornutum (Harlan)

Two specimens (Nos. 265♀ and 4379♂) were collected, the former in Nuevo León, twenty miles south of Nuevo Laredo, on June 8, 1932, the latter in Durango, seven miles south of La Loma, on August 25, 1932. Apparently there is no other record of the species from the latter state.

Measurements and Scale Counts of *Phrynosoma cornutum* (Harlan)

Number	*4379*	*265*
Total length	96.0	120.0
Snout to ear	12.0	14.0
Width of head	19.0	19.0
Fore limb	29.5	36.0
Hind limb	42.0	54.0
Tail	29.0	26.0
Upper labials	9–9	8–10
Lower labials	9–10	11–11
Enlarged infralabials	8–8	8–9

Phrynosoma modestum Girard

Two specimens (Nos. 4378♀, 4410♀) of this diminutive species were collected, the former in the state of Durango, seven miles south of La Loma, on August 25, 1932, the latter in Coahuila, one and one-half miles west of Saltillo,

on August 24, 1932. This is apparently the first report of the species so far south as Durango.

Both specimens agree in most respects with available descriptions and in comparison with specimens from southwestern United States. A distinct, small, pointed scale separates the two posterior temporal spines; supraorbitals nearly uniform in size, smaller than supraoculars; a small row of spines at sides of base of tail. No. 4410 is much darker than most specimens; the lateral dark blotches are extended dorsally and diffused over the entire dorsolateral region, leaving an indistinct median dorsal light area; the dark lateral blotches on the sides of the base of the tail are also diffused and indistinct; the gular region and the proximal anterior aspect of the humerus are diffused with darker; an indistinct median ventral dark area is present on the breast.

MEASUREMENTS AND SCALE COUNTS OF *Phrynosoma modestum* Girard

Number	*4378*	*4410*
Total length	73.0	65.5
Snout to ear	9.5	8.5
Width of head	13.3	11.0
Fore limb	23.0	22.0
Hind limb	28.0	28.0
Tail	24.0	22.5
Femoral pores	6–7	11–12
Upper labials	9–10	10–9
Lower labials	10–11	10–11
Enlarged infralabials	9–8	8–8

Phrynosoma orbiculare orbiculare Gray

Two specimens of *Phrynosoma orbiculare* were secured. So marked are the differences between the two that they have here been considered subspecifically distinct, following the classification first proposed by Bocourt (1874). It may be noted that Terron (1932) has lumped all subspecies.

The specimen here considered with the typical subspecies (No. 4591♀) was collected near K57, between Mexico City and Cuernavaca, in the state of Morelos, on July 30, 1932. It was found on a cool day, late in the afternoon, during a short interval of sunshine, in an open grassy area in the high plateau region.

The specimen may be described as follows:

Head about as broad as long; nostril pierced somewhat within the line of the canthus rostralis; upper labials 7-8, the posterior ones faintly keeled; lower labials 12-13, the posterior ones keeled, the last long and pointed; infralabials about the same size as the lower labials, in contact with the latter in the mental region, separated by 2-3 scale rows in the posterior region; gular scales smooth, becoming slightly enlarged posteriorly near the gular fold, but not so large as the smooth abdominals; head scales rugose; on each side a short superciliary spine, a single occipital, and two large and one small temporal; the occipital spines project back of a line connecting the tips of the longest temporals about 1.3 mm. and are actually about 1.6 mm. longer than the longest temporal; cephalic spines nearly flat and in about the same plane, the general direction of the occipital spines outward from the median line; three to five enlarged scales in front of and between occipitals; dorsal scales of humerus keeled and somewhat larger than ventral abdominals; scales of posterior aspect of lower forearm keeled, those of anterior aspect and of digits smooth; scales on ventral

surfaces of hind limbs smooth, nearly or quite as larger as ventral abdominals, and continued onto the anterior aspect of femora and tibiæ, where some are keeled; dorsal scales of foot keeled; dorsal surfaces of back, tail, femora and tibiæ covered with granular scales and scattered larger, keeled, and pointed scales; the latter not present in the mid-dorsal line except near occiput, arranged in rows on the tail; these enlarged tubercles somewhat larger on femora, tibiæ and tail than on body; a single series of enlarged laterals from axilla to groin; 19 femoral pores on each side, in contact in front of anus and forming a double series near the median line.

A strong gular fold, the scales of which are granular and of about the same size as the smaller dorsals; gular fold terminating laterally in a deep pouch anterior to forelimbs, granular scales lining the same; one small and one large fold of skin anterior to nuchal pouch, the larger bearing three or four enlarged, pointed scales; tympanum bare; a small fold above insertion of foreleg, also with enlarged scales.

General color rather dark; a dark spot on either side posterior to occiput, separated medially by a conspicuous light area, and bordered posteriorly by a narrow light band; a series of four such light bands on either side of body, and perhaps three more on the tail, fading away toward tip; each light crossbar extended from lateral spines to near median line, and bordered anteriorly by a dark area which becomes somewhat lighter posterior to the next light crossbar; dorsal surfaces of limbs of about the same color as back, with a slight banded effect; dorsal surface of head uniformly dark brown; ventral surfaces whitish, coarsely reticulated with black on lower surfaces of limbs, tail and abdomen, somewhat more finely in gular region.

Total length, 123 mm.; snout to ear, 15.0 mm.; width of head, at angle of jaws, 16.5 mm.; greatest width between superciliary ridges, 10.7 mm.; median length of occipital horn, 5.5 mm.; median length of posterior temporal, 3.9 mm.; ventral scale rows, 61; upper labials, 7-8; lower labials, 12-13; enlarged infralabials, 12-14.

Phrynosoma orbiculare cortezii (Bocourt)

A single specimen of this form (No. 1845♀) was collected in the state of Vera Cruz, 15 miles east of San Marcos (about 55 miles west of Perote), on July 12, 1932. It was found sunning itself along a railroad track on a rather warm day.

This individual differs from the preceding in the following respects: Head considerably broader than long; nostril pierced in the line of the canthus rostralis; lower labials 14, the posterior four larger than in *orbiculare;* the series of enlarged scales below posterior labials not nearly so large as posterior lower labials; upper labials 8-9; the tips of occipitals about 1 mm. within a line connecting the temporals, and directed mesad instead of laterad, as in *orbiculare;* scales of anterior aspect of humerus more strongly keeled and pointed; dorsal scales of lower forearm keeled; the scales of posterior surface of lower forearm elongated to form a series of spines; scales of dorsal surface of hand keeled; enlarged scales of back, hind limbs and tail noticeably larger than those of *orbiculare;* ventrals somewhat smaller; enlarged scales of the folds about the nuchal pouch larger.

Entire coloration much lighter, the markings indistinct, although of the same general pattern; lower surfaces of limbs almost entirely whitish.

Total length, 116 mm.; snout to ear, 16 mm.; width of head, at angle of jaws, 21.5 mm.; greatest width between superciliary ridges, 12 mm.; median length of occipital, 4.4 mm.; median length of posterior temporal, 4.2 mm.; ventral scale rows, 71; upper labials, 8-9; lower labials, 14-14; enlarged infralabials, 12-13.

I am indebted to Dr. Edward H. Taylor for much valuable advice concerning the preparation of this paper; to Mr. C. D. Bunker, curator of Dyche Natural History Museum of Kansas University, for permission to examine and compare specimens in the herpetological collection of that museum; and to Dr. H. H. Lane for valuable assistance with regard to equipment and photographs.

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PLATE XI

FIG. 1. *Phrynosoma orbiculare cortezii.* Dorsal aspect of female (No. 1845). Actual total length, 116 mm.

FIG. 2. *Phrynosoma orbiculare orbiculare.* Dorsal aspect of male (No. 4591). Actual total length, 123 mm.

FIG. 3. *Phrynosoma modestum.* Dorsal aspect of female (No. 4410). Actual total length, 65.5 mm.

FIG. 4. *Phrynosoma braconnieri.* Dorsal aspect of male (No. 3121). Actual total length, 44.5 mm.

PLATE XI

PLATE XII

FIG. 5. *Phrynosoma orbiculare orbiculare*. Ventral aspect of specimen shown in figure 2.

FIG. 6. *Phrynosoma orbiculare cortezii*. Ventral aspect of specimen shown in figure 1.

FIG. 7. *Phrynosoma asio*. Dorsal aspect of female (No. 963). Actual total length, 170 mm.

PLATE XII

Studies on the Reproductive Systems of *Gryllus assimilis* Fabr

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(TWO TEXT FIGURES AND PLATES XIII TO XXI)

I. REVIEW OF LITERATURE

The literature on the reproductive system of the Gryllidæ is voluminous, yet there are many unsolved problems and many details that have not been worked out. Many misinterpretations have crept into the literature, due to the fact that most of the previous work has been done on preserved specimens or fixed material.

Burmeister (1836) said that the peculiar glandular appendages, which are probably gluten-secreting organs, are found in both male and female insects, but, in general, they are more numerous in the males than in the females. He says that since there is a deficiency of them in one sex in some insects that this is opposed to the opinion of Suckow that they secrete urine. He also states that they unite with the sperm duct to form the ejaculatory duct. According to his description and location of these glands they must be the accessory glands.

Dufour (1841) described the male genital apparatus of some of the Gryllidæ.

Siebold (1845) described the transfer of the spermatoza from the male to the female by means of a spermatophore, but thought that the spermatophore is the end of the penis broken off and that it is reformed. He also gives a description of the glands attached to the ejaculatory duct and found that their secretion coagulated quickly when exposed to the air.

The spermatophore of the cricket has been studied by Yersin (1853) and by Lespés (1855). The latter gives a rather detailed description of copulation and of the spermatophore of *Gryllus campetris* and *G. domesticus*, but gives no interpretation of the annexed glands. In another article he described the spermatophore, the male reproductive system, and the development of the spermatozoa of *G. sylvestris*. His work shows a great deal of care and accuracy, but later it was questioned by Milne-Edwards (1870). According to the view of Milne-Edwards (1870), the spermatophores of Stein (1847), Siebold (1845) and Lespés (1855) are terminal portions of the penis which are broken off during copulation and left inserted in the vagina of the female. As Baumgartner (1910) suggests, this is probably the reason Lespés' work has not received proper recognition.

Graber (1877-79) recognized the fact that in many Orthoptera the spermatozoa are transferred by a spermatophore.

Girard (1879) gave an account of the method of transferring the spermatozoa of *G. campestris*, and quotes Lespés (1855) in describing the spermatophore.

Berlese (1882) said that fertilization is internal and that copulation in the Acridida and probably in the Mantidæ is effected by means of a penis, the act lasting a long time; but in the Locustidæ and the Gryllidæ the male

mounts the female, inserts the penis in the vagina, and the spermatozoa are soon injected. He postulated that the mucus secretion of the annexed gland acts as a lubricant, but also noted that it passes out of the deferent canal. He stated that fecundation is more complex in *Gryllus,* occurring by means of a special organ, a spermatophore, which holds the spermatozoa in the interior and which is left in the vagina of the female, and may be reformed as many as three times a day (p. 33).

Peytoureau (1895), who studied the external genitalia of many insects, including Orthoptera, said that in the Orthoptera there does not generally exist a penis at the extremity of the genital orifice except in the Acrididæ, the Forficulidæ, and the Ephemeridæ (p. 127).

Fenard (1897), who studied both sections and dissections of the internal complementary organs of the genital apparatus of the Orthoptera, described the structure and function of the annexed glands.

It is interesting to note the statement of Packard (1898): "Among the winged insects the reproductive organs of the cricket (Fig. 466) are perhaps as simple as any. The testes are separate, and the vasa deferentia very long. The seminal vesicles bear numerous long and short utricles (*utriculi majores* and *breviores*), the penis being simple and dilated at the end" (p. 487). The figure to which he referred is one of Lang's (1891) drawings. But on page 499 Packard (1898) said: "In many insects which lack a true penis the bundle of spermatozoa are united in the ejaculatory duct, forming packets, which are enveloped by the secretion of the accessory glands, which stiffens into a hard case."

Snodgrass (1903) in his description of the internal anatomy of *Peranabrus scabricollis* (Thom.), a locustid, described two sets of accessory glands, one large and the other small. He postulated that these glands secrete the mass of albuminous material, which is injected into the bursa copulatrix of the female after copulation, but does not mention how the spermatophore is formed. He stated that five spermatophores were found in the spermathecas of the specimens examined.

Concerning copulation of *Œcanthus fasciatus* Fitch, the striped tree cricket, Blatchley (1903) said that it seems that the female mounts the male and that the latter raises his tegmina, giving the female access to a pair of glands which are situated beneath the wings. He stated that neither any intromittent organ of the male nor any union of the reproductive organs of the two sexes were observed. Then he suggested that the female removes the semen from the glands beneath the tegmina of the male and then fertilizes her ova. Hancock (1905) observed the act of copulation in *Œcanthus fasciatus* and proved Blatchley's idea to be entirely erroneous. He considered the glands secondary sexual organs for the purpose of alluring the female. Howard (1905) quoted Harrington as saying "the female may be seen with her head applied to the base of the wings, evidently eager to get full benefit of every note produced" (p. 344).

Gillette (1904) noticed that the seminiferous tubules of *Anabrus simplex,* a wingless grasshopper, were filled with a milky fluid before copulation, but were empty and yellow after copulation. He concluded that the males filled the white sacs with seminal fluid during copulation and then transferred them to the females. According to him, copulation of this species lasted about ten minutes.

Henneguy (1904), in his text "Les Insectes," in discussing the annexed glands said that there may be one, two, or three sets which secrete a substance which coagulates and forms a spermatophore. In his description of copulation of *Gryllus* he quotes Lespés (1855) and presents some of his figures, but he also gives the simple figure given by Packard (1898) to represent the reproductive system of the cricket.

Houghton (1909) observed the transfer of the spermatophore from the male to the female in *Œcanthus,* and stated that three were formed one day. He presented another view concerning the "alluring glands" of Hancock (1905). He said that these glands may be for the purpose of alluring the female, "but why does she continue to work away at this organ for a considerable period of time after the object of their union has been accomplished—the reception by the female of the sperm sac? Can this be a provision of nature to keep her attention occupied for a time in order that the spermatozoa may have time to pass into her organs? If not thus entertained, possibly she would detach the sac at once upon receiving it from the male" (p. 279).

Baumgartner (1910) reviewed Lespés' work in detail and described the copulation of *Nemobius* and *Gryllotalpa.* He stated the mechanical problems involved in the formation of the spermatophore and suggested that the spermatozoa are forced to flow out of the spermatophore.

Jensen (1911) considered that the spermatophores of crickets may be of taxonomic utility. He briefly described the spermatophore and gave the function of its parts. He said that in *Gryllus* the anterior part of the handle of the spermatophore was held tightly inside the vaginal opening by means of the anterior hooks. He also stated that when he removed the bulb of the spermatophore the handle broke off, but that when the "whip-like structure" was pulled out it was evident that it had extended a considerable distance up the passage. This would indicate that the spermatheca is some distance from the external orifice.

Boldyrev (1913) described the spermatophores of *Gryllus domesticus* C., *G. desertus* Pall., and *Œcanthus pellucens* Scop.

Gerhardt (1914, 1921) quoted Boldyrev (1913) in his description of the spermatophore of *Œcanthus pellucens* and described the copulation of *Nemobius sylvestris.*

Turner (1916) in describing copulation of the Gryllidæ said that the female mounts the male and the spermatophore is placed in the vulva of the female by the male, the act lasting only a few minutes, but they remain in this position for a short while. He stated that the female begins gnawing at the spermatophore before the spermatozoa have time to enter the oviduct and would soon devour it were it not for the fact that her attention is directed to a secretion from some glands at the base of the wings of the male.

Cappe de Baillon (1919) presented an extensive anatomical and physiological study of the reproductive organs of the Gryllidæ and the Locustidæ.

Walker (1919-'22) made a phylogenetic study of the terminal structures of the Orthoptera in which he homologized the structures of the different families

DuPorte (1920) showed the relation of the muscles to the reproductive system in both sexes of *Gryllus assimilis.*

Ford (1923) figured the attachment of the muscles to the reproductive organs of *Gryllus assimilis.*

Concerning copulation of crickets, Lefroy (1923) wrote, "During copulation the male creeps beneath the female and extrudes the spermatophore, which acts as a copulatory organ" (p. 75). He said that the spermatophore consists of a muscular walled vesicle, carrying at its posterior extremity a white papilla and at the other extremity a chitinous plate in the middle of which is a tube communicating with the interior of the vesicle and carrying the hooks which hold the spermatophore in the vulva.

Ito (1924) described in detail the annexed glands of both sexes of the cricket. He said that the Gryllidæ do not possess a penis, but that there are two types of accessory glands of the male *Gryllus;* the anterior ones secrete a substance which forms the spermatophore and the posterior ones secrete a substance which nourishes the spermatozoa.

Comstock (1925) said that the spermatozoa of the Locustidæ, Gryllidæ, and some Lepidoptera are inclosed in a sac, a spermatophore, which is transferred by the male to the female.

Schröder (1928) recognized that in Locustidæ and Gryllidæ the spermatozoa are transferred in a spermatophore.

Carpenter (1928) said that the accessory glands of insects secrete a fluid which unite the sperms in bundles so they can be transferred to the sperm receptacle of the female. He also said that the male insects have an ejaculatory duct terminating in an intromittent organ which may be tubular or may have a basal bulb.

Fulton (1931) said that "the formation of the spermatophore (in Nemobius) is a complicated process which is difficult to understand," but that it is formed from the secretion of the accessory glands.

Snodgrass (1933) gave in detail the structure of the ovipositor, the origin and insertion of the abdominal muscles, and the mechanism of oviposition in *Gryllus assimilis.* He presents two figures showing the spermatheca and its associated structures.

II. MATERIALS AND METHODS

The crickets were collected under stones on and near the university campus at Lawrence, Kan. During the height of the breeding season they were collected at about 10:30 at night in the grass around the lights. At this time they could be collected by the hundreds. The two sexes were separated, placed in insect cages, and fed and watered.

The intravitam technique worked out by Baumgartner and Payne (1930-'31) was used in a part of this investigation. All the dissections were made upon living material in Belar's solution under a dissecting microscope. The organs of the reproductive systems of both sexes were studied in their normal position in the body; then they were removed from the body after the connective tissue and tracheal tubes had been dissected away, placed on a slide in the nutrient fluid, and covered with a coverslip, the edges of which were sealed with melted paraffin. After gross examination, successive parts of the genital systems were studied with low- and high-power objectives and photomicrographs were taken of these preparations.

For the histological studies the tissues were fixed in Bouin's fluid and stained in Delafield's hematoxylin and eosin.

For observations on copulation a male and a female were placed in a pint fruit jar and close observations were made. Sometimes grass was put into the jars.

III. FEMALE REPRODUCTIVE SYSTEM

The ovaries and oviducts of insects are derived from the mesodermic somites and the vagina is derived from the ectoderm. The oviducts meet and fuse with the integumental invagination which forms the vagina (Wheeler 1893). The bursa copulatrix and the spermatheca are ectodermal in origin. The bursa copulatrix may be a diverticulum of the vagina or it may have an external opening (Comstock 1925). Folsom (1922) says that the spermatheca in most insects is formed by a dorsal evagination of the vagina.

In nymphs of *Gryllus assimilis*, with a body length of 10 mm., the ovaries are somewhat spherical and the oviducts are long, slender string-like structures (Fig. 10) without a lumen. The vagina, bursa copulatrix, and spermatheca are not developed at this stage. In nymphs (body length 17 mm.) the ovaries have enlarged, the oviducts have shortened and thickened, and the ectodermal invagination has met and fused with the oviducts forming the vagina (Fig. 11).

The spermatheca begins as an ectodermal invagination in nymphs with a body length of 12 mm. (Fig. 1). When the body length has reached 15 mm. the invagination has formed a long convoluted tube with a lumen (Fig. 2) and by the time the body length has attained 17 mm. the tube at the distal end has become distended into a bulbous organ (Fig. 6).

The ovaries in the adult are somewhat spindle-shaped while they are attached in the body, but are more or less oval when they are removed. They lie in the upper lateral part of the abdominal cavity extending from the first back to the seventh segment, where they join the oviducts. The ovaries and the rest of the female reproductive system of the nymph (body length 10 mm.) are enveloped in a yellowish, fatty, lobated tissue, but most of this has disappeared in the adult. They are aërated by six tracheal tubes which enter from the side and bifurcate, one branch passing around to the dorsal side and one to the ventral side.

The ovaries of an adult, in situ, are about 7 by 5 mm. The size of these organs vary with the stage of development of the eggs, and with the amount of oviposition.

A connective tissue surrounds the ovaries enveloping the ovarian tubes. The ovarian tubes of this species do not have nurse cells. These tubules are lined with an epithelial layer which is followed by a basement membrane and a connective tissue layer.

The terminal filaments of the ovarian tubes are filled with a clear hyaline protoplasm. These strands are about 2 mm. long. The large nucleated primordial germ cells are entangled in the network of protoplasm (Fig. 18). In the vitellarium there is a single continuous row of egg cells. The walls of the ovarian tube are constricted between each egg cell in this region, thus giving it the appearance of a string of beads (Fig. 12). These tubules enter the oviduct by a short stalk (Figs. 16 and 17). Each ovary contains an average number of 125 ovarian tubules (Fig. 14).

The mature egg is elongate oval in shape and is slightly curved (Fig. 15). It is about 3 by 5 mm. The chorion or egg-shell must be secreted by the

follicular epithelium, since no glands were found connected with the oviducts or vagina. From 30 to 40 eggs with firm shells, apparently ready for deposition, and others in all stages of maturity are usually found in each ovary during the breeding season. The oviducts are short tubes about 3 mm. long. They extend posteriorly from the ovary, passing under two muscles before they reach the median external passage, the vagina. According to Du Porte (1920, Fig. 34) the first muscle under which they pass is the adductor muscle of the subgenital plate and the second one is the retractor muscle of the vagina. The vagina is about 1 mm. long and is lined with chitin.

The bursa copulatrix (called by Snodgrass spermathecal spout) is a brown chitinous organ located upon the dorsal wall of the vagina (Fig. 9), but there is no passage from the bursa copulatrix to the vagina. This is called the bursa copulatrix because the male places the capillary tube of the spermatophore into the orifice of this organ during copulation. From the dorsal side it appears as an isosceles triangle, but, when the muscles and all the attachments are removed and all the muscles and tracheal tubes are dissected out from between the dorsal and ventral sides, it appears to have the shape of a kite (Fig. 8).

The dorsal side is oval and slightly curved, making the posterior end slightly lower than the anterior end. The ventral side is practically flat and has an external opening about 0.25 mm. from the posterior end (Fig. 3) into which the male places the capillary tube of the spermatophore during copulation (Figs. 62 and 63). This orifice opens into the spermathecal canal which passes through the center of the bursa copulatrix. This canal gets a little smaller toward the anterior part of the bursa copulatrix. The anterior part of the ventral side of the bursa copulatrix extends beyond the dorsal (Text fig. 1, B). From the posterior end to the anterior end of the ventral side is about 1 mm. and the dorsal side is less. The widest part of the ventral side is about 0.5 mm. The entire area between the dorsal and ventral sides is filled with muscles and tracheal tubes while the spermathecal canal occupies the center. The opening is just dorsal to the vaginal opening; therefore, the egg must be fertilized just before oviposition as it passes out of the vagina.

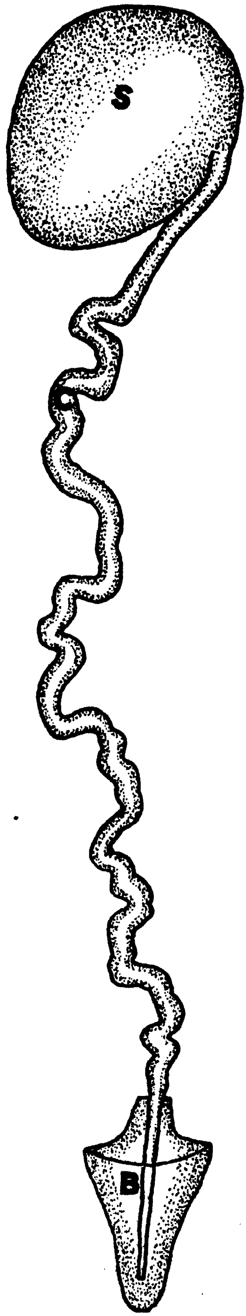
Comstock (1925) in referring to the bursa copulatrix says, "In some insects this pouch is a diverticulum of the vagina (Fig. 177, b c); in others it has a distinct external opening, there being two external openings of the reproductive organs, the opening of the vagina and the opening of the bursa copulatrix.

"When the bursa copulatrix has a distinct external opening there may or may not be a passage from it to the vagina. In at least some Orthoptera (*Melanoplus*) there is no connection between the two; when the eggs are laid they are pushed past the opening of the bursa copulatrix, where they are fertilized" (p. 160).

Ito (1924) says that the canal of the spermatheca opens in the dorsal wall of the vulva in *Acheta campestris* L.

Fulton (1931) states that in *Nemobius* the tube of the spermatheca passes through a knob-like invagination of the dorsal wall of the vagina.

Lespés (1855), Boldyrev (1913), Gerhardt (1921), and others say that the male places the canal of the spermatophore in the vagina of the female. The capillary tube of the spermatophore is placed in the opening of the bursa copulatrix, which never enters the vagina in this species. It is evident that the



TEXT FIGURE 1. Projection drawing of a dorsal view of the bursa copulatrix, spermathecal canal, and spermatheca of *Gryllus assimilis*. B, bursa copulatrix; C, spermathecal canal; S, spermatheca. × 10.

species which they worked upon are different from *Gryllus assimilis* or they failed to work out the female reproductive system and just took it for granted that the capillary tube is placed in the vagina.

The canal that extends from the bursa copulatrix to the spermatheca is a convoluted tube about 10 or 12 mm. long (Fig. 7). In the normal position in the body this tube is so convoluted and the convolutions are so close together, being held this way by connective tissues, that the spermatheca is only 2 or 3 mm. from the bursa copulatrix (Fig. 9). The lumen of the canal is lined the entire distance with chitin, and the canal has the same structure as the spermatheca. The canal enters the spermatheca near the anterior end, passes straight down the side of the spermatheca until it reaches the posterior end, and then becomes convoluted (Text Fig. 1). The spermatheca and the canal are enveloped in a connective tissue which binds them so closely together that without a very careful examination it would appear that the canal entered at the posterior end of the spermatheca (Fig. 9).

The spermatheca is an oval pouch about 3 mm. long and 1.5 mm. wide. As might be expected, there are some variations in the size and shape of the spermatheca in the different individuals, depending upon the size and age of the individual, and the amount of spermatozoa that have been injected into it from the spermatophores. It lies in the median ventral part of the abdomen just beneath the digestive tract and between the oviducts.

IV. MALE REPRODUCTIVE SYSTEM

According to Wheeler (1893) the testes, the vasa deferentia, and the seminal vesicles of insects are mesodermal in origin, and only the ejaculatory duct and its accessory glands are ectodermal. Nusbaum (1884) concludes that the testes and vasa deferentia are mesodermal while the seminal vesicles, ejaculatory duct, and the accessory glands are ectodermal. Comstock (1925) describes the seminal vesicle as "an enlarged portion of the vas deferens, serving as a reservoir for the products of the testis." This is true of *Gryllus assimilis;* therefore, the seminal vesicle would have the same origin as the vas deferens and would be mesodermal. Escherich (1894) divides the accessory glands into two types: (1) mesadenia, those derived from mesoderm, and formed as evaginations of the vas deferens, and (2) ectadenia, those derived from ectoderm, and formed as evaginations of the ejaculatory duct.

The male reproductive system of a nymph (body length 12 mm.) is very simple, being composed of two small testes, the straight vasa deferentia, and a pouch or ampulla from which the accessory glands develop (Fig. 19). The vasa deferentia are small ducts which pass under the suspensory muscles of the spermatophore cup on the eighth segment and then enter the ampulla. They are about 3 mm. long. There is no lumen in the ducts at this time except towards the ends, where they widen into the terminal ampulla. At this stage of development there is no external opening of the sperm ducts. The terminal ampulla is located at the posterior ventral part of the abdomen between the cercal nerves. The testes, vasa deferentia, and terminal ampulla are covered with a yellowish, fatty tissue, which is full of fat droplets.

In nymphs 18 mm. long the vasa deferens has increased in size and the ampulla has become more prominent (Fig. 20). This stage resembles very much the simple figure of Lang (1891) used by Packard (1898) and Henneguy (1904). In nymphs (body length 20 mm.) the vas deferens after it passes

under the muscle becomes convoluted and forms the seminal vesicle for the storage of the spermatozoa, and the ectodermal invagination meets and fuses with the terminal ampulla forming the ejaculatory duct and its accessory pouches and the spermatophore mold.

In the adult the reproductive system is much more complicated than in the early nymph stage, consisting of a pair of testes, vasa deferentia, and seminal vesicles, an ejaculatory duct with two accessory pouches, a spermatophore mold, and two lateral pallets.

The testes are whitish organs lying on each side of the abdomen from the first to the sixth segment. They are shaped somewhat like a strawberry, with the smaller end extending posteriorly (Fig. 24). The testes, in situ, are 5 by 3 mm. There are approximately 280 follicles to each testis. The follicles are slightly spindle-shaped. Each follicle is about 4 mm. long and is attached to a central duct by a slender tube (Fig. 25) about 15 mm. long. The small tube which connects the follicle to the central duct bends backward, thus making the blind end of the follicle extend posteriorly and the open end anteriorly. Connective tissue surrounds the entire testis, holding the follicles together.

The vas deferens leaves the posterior part of the testis, passes posteriorly along the ventral abdominal muscles until it reaches the eighth segment, where it passes under the suspensory muscle of the spermatophore mold. It is a straight tube about 5 mm. long and about 0.10 mm. in diameter. After it passes under the muscle it becomes enlarged and convoluted, forming the seminal vesicle (Fig. 35). The seminal vesicle is translucent before it becomes filled with spermatozoa, after which it becomes a glistening white. The convoluted tube or seminal vesicle, which is covered by the accessory glands, enters into a pouch or ampulla (Fig. 33, AM) into which the accessory glands also open. The seminal vesicles cover a space of 3 mm: when they are convoluted, but when extended they are about 10 mm. long and have a diameter of about 0.50 mm.

The accessory glands are the most conspicuous organs of the abdomen. They completely surround the seminal vesicles and extend backward over the spermatophore mold and forward over the intestinal tract. There are hundreds of these glandular tubules, which vary greatly in length and diameter. There are two sets of accessory glands: (1) one set is composed of long milky white tubules (Fig. 32) varying from 5 to 10 mm. in length and from 0.03 to 0.08 mm. in diameter, and (2) the other set consists of short, glassy tubules (Fig. 31) varying in length from 1 to 5 mm. and from 0.03 to 0.05 mm. in diameter. The first set of tubules is filled with a milky white secretion which coagulates readily when exposed to the air and takes a cytoplasmic stain. When these tubules are mounted in the nutrient medium and observed under the microscope it can be seen that the secretion is forced out of the blind end of the tube by the muscular contraction of the wall. The second set of tubules contains a clear granular secretion which takes a nuclear stain. Judging from the appearance of the secretions and the stains which they take, the secretion from the milky white tubules must form the middle layer of the ampulla and the outer layer of the capillary tube of the spermatophore, and the secretion from the glassy tubules must form the inner lining of the ampulla and the capillary tube and the outer layer of the ampulla and the plate of the spermatophore

The ejaculatory duct is a short duct about 2 mm. long, lined with chitin, extending from the accessory glands to the spermatophore mold. On either side of this duct is a pouch or gland (Figs. 29 and 30, A) which has a short tube that enters the ejaculatory duct just before it enters the spermatophore mold. They are oval, glassy pouches, almost spherical, having a diameter of about 0.4 mm.

These pouches are lined with a thick layer of chitin with irregularly distributed small, conical protuberances. The epithelial layer is made up of tall columnar cells with their nuclei near the chitinous intima. The muscular layer is very thin. No secretion was found in the lumen of the glands.

Lespés (1885) found these glands in *Gryllus sylvestris*, but failed to find them in *G. campestris* and *G. domesticus*. He does not give their function, but says that they are well developed in the Locustidæ. Ito (1924) calls them prostatic glands. He says that in *Acheta campestris* (= *Gryllus campestris* L.) and in *Gryllomorpha dalmatina* Oesk. they are oval masses closely attached to the posterior extremity of the ejaculatory canal into which they open by a short passage. He states that in *Gryllus* the mucous secretion of these glands lubricates the ejaculatory duct, facilitating the passage of the spermatophore. Fulton (1931) found these structures in *Nemobius* and called them "accessory pouches whose function is unknown."

The posterior end of the ejaculatory duct opens into the spermatophore mold (Fig. 21, SM). The mold is about 2.5 mm. long on the dorsal side, 2 mm. long on the ventral side and is about 1.5 mm. from the dorsal to the ventral side. It is lined with a thick layer of chitin (Fig. 40).

The spermatophore mold is made up of two parts: a part for the plate and capillary tube and a part for the vesicle (Fig. 38). The white plate with cross striations has five hooks (Figs. 38 and 39). In the dorsal median line of the plate is a groove in which the tube which passes through the plate is formed. This groove continues from the plate as a hard, brown chitinous tube (Fig. 41) in which the capillary tube of the spermatophore is held. The plate bends up dorsally over the open vesicle in which the ampulla of the spermatophore is formed. The vesicle is open on the ventral side, from which the ampulla of the spermatophore protrudes (Fig. 21, S). This vesicle is closed by the contraction of the yellowish-brown muscular pallets (Fig. 42, PL) which support the ampulla of the spermatophore. At the posterior part of the mold are three brown chitinous hooks (Figs. 21, H, 44, and 45) which the male uses for clasping the female during copulation. The spermatophore mold is so constructed that the spermatophore when it is in the mold is so bent upon itself that the end of the vesicle or ampulla and the end of the capillary tube almost meet; the plate and the tube being bent back dorsally over the ampulla.

Just after copulation, when there is no spermatophore in the male cricket, the hooks are lowered, the subgenital plate is raised, and the pallets are contracted, forming a sort of plug for the spermatophore mold.

After the ampulla of the spermatophore is ejected from the mold it is held by the two pallets, one on either side. They are also used by the male in transferring the spermatophore from the male to the female. The pallets are about 1.25 mm. long and 1 mm. wide.

V. TURNING AND MOVEMENTS OF SPERMATOZOA

As stated before, each testis is made up of approximately 280 follicles which are about 4 mm. long. They empty by a short canal into a central duct which continues from the posterior end of the testis as the vas deferens.

The four regions of the follicle are readily recognized: (1) At the blind end of the folicle is the germarium which contains the primordial germ cells and the spermatogonia (Fig. 69). (2) The zone of growth containing the primary and secondary spermatocytes (Fig. 69). (3) The zone of reduction and division producing the spermatids (Fig. 65), and (4) the transformation zone in which the spermatids are transformed into spermatozoa (Fig. 76).

The follicles are small, turgid, tubular, spindle-shaped structures. In the early nymph stage the cysts of the follicles are all rectangular in shape and extend across the entire folicle, except the one at the open end of the follicle, which is elongated and pointed at the proximal end (Figs. 64 and 67). These cysts differ from those of the grasshopper in that those of the grasshopper are spherical and it takes several of them to reach across a follicle (Baumgartner and Payne 1931, Fig. 14). In the spermatogonial region at the blind end of the follicle the cysts are closely packed together, making them very narrow. The outer walls of the cysts closely adhere to the walls of the follicle. In cysts of cells in division stages the fourteen and fifteen chromosomes observed by Baumgartner (1904) in fixed material are easily counted in the living material. In the proximal end of the follicles of mature crickets all of the cysts walls are broken down and the spermatozoa are crowded closely together (Fig. 77).

Baumgartner (1930) suggested the turning of the spermatozoa in the Acridian follicle. In 1929 he found that in the Gryllid, *Nemobius fasciatus*, the heads are turned toward the open end of the follicle while the spermatozoa are elongating.

In *Gryllus assimilis* the spermatids in the first cyst at the proximal end of the follicle turn within the cyst and have their heads directed toward the open end of the follicle before maturity. In figure 67 the tails of the spermatids can be seen twisted in a spiral in the upper end of the cyst, and part of their heads are directed toward the closed end of the follicle and part toward the open end, but in figure 68 all of them have turned and have their heads towards the open end. They remain crowded in this position until maturity, then they break out of the follicle (Fig. 77) and pass out into the vas deferens. However, this is not true for the spermatids of the remainder of the cysts of the follicle. They do not turn within the cyst, but break out of the cyst, spiral up the follicle, turn in the spermatid region (Fig. 73), and spiral back down the follicle.

In the cysts above the proximal one the spermatids in the very early stages seem to be scattered promiscuously (Fig. 65), but when they begin to elongate the cell bodies begin to move toward the periphery and the tails toward the center (Fig. 66). In a later stage the cyst wall pulls loose from the follicular wall and the cyst becomes almost spherical, with the spermatids radiating out from the center (Fig. 68). Later, as elongation continues, the cyst elongates and the spermatids begin directing their heads toward the blind end of the follicle (Fig. 70). Finally, as the cysts elongate, all the heads point toward the blind end of the follicle (Figs. 71 and 72). Then the spermatids break out

of the cyst, pass up the follicle, spiral across and back down the follicle. The spermatids of each cyst remain in a group and travel together, but their heads are not bound together by a cytoplasmic cap as in *Chortophaga* (Payne 1933). Three such groups may be seen in figs. 74 and 75. They pass out of the follicle and the vas deferens in these bundles. It is probably just one of these bundles that enters in the ampulla of the spermatophore when it is formed. If the bundles are bound together in any way it could not be detected, and, if so, they are separated before they pass out of the capillary tube of the spermatophore, because they pass out one, or at most only a few, at a time. This pseudo-aggregation is always broken up when they are liberated into the medium.

Since the spermatids above the first cyst spiral up the follicle, turn, and spiral back down the follicle; what is the reason that those in the first cyst do not do likewise? Several reasons might be presented. First, this cyst is longer and there is more room for them to turn. Second, the cysts above this one are closely appressed to the follicular wall and no pathway between the cyst and the follicular wall is yet formed in which they can travel. Third, there is always some stored material, whitish milky fluid and cellular substances, in the first cyst (Fig. 64, middle follicle) which probably serves as a nutritive substance, thus causing them to mature more rapidly than the others.

Always many more bundles of spermatozoa are observed going up the follicles than down. Payne (1933) suggests several reasons for this: (1) difference in physiological development of the spermatozoa themselves, (2) in traveling down the follicle less pressure is probably encountered, and (3) bundles that are going down the follicle are not going against the force of gravity.

The movement of the spermatozoa in the follicles is periodic. At first, the tails begin to writhe and twist, then the entire bundle moves a very short distance, then ceases to advance. This continues for some time and then the last advancement is more prolonged than the others. During some observations the spermatozoa were in motion for 30 minutes; during others, they were in motion for more than an hour. The methods of movement and turning is a spiraling process. They spiral from left to right.

The bundles of spermatozoa pass down the vas deferens in single file, one bundle following another (Fig. 26). The spermatozoa are active in the vas deferens and show the same spiraling movements there as in the follicles of the testis. When the walls of the ducts were ruptured the spermatozoa passed out readily and were very active in the nutrient medium. They spiral through the medium at a very rapid rate for a long period of time. When the spermatozoa are liberated the pseudo-aggregations break up and the individual spermatozoa go writhing and lashing in every direction.

The seminal vesicle is packed and crowded with spermatozoa and a milky white fluid. The spermatozoa are still active when set free in the nutrient fluid from these ducts.

The mature spermatozoa (Fig. 81) have long, rod-shaped heads and long tails, as described by Baumgartner (1902). The heads are about 0.08 mm. long and the tails are about 0.83 mm. long, making a total length of 0.91 mm. Spermatids with round heads and with blebs down the tails are shown in fig. 79. As the spermatids mature the blebs disappear (Fig. 80.)

The male transfers the spermatozoa in a spermatophore from the spermato-

phore mold to the bursa copulatrix of the female. Then they must travel up a 12-mm. tube before they reach the spermatheca, where they are stored. The question arises, how do they get up this tube? The force that forces them out of the spermatophore, no doubt, helps a little, but it is not sufficient to force them the entire distance. Their own activity most probably is the greatest factor in taking them up the tube, but there may be another force that plays a part in their passage, and that is the peristalic movement of the spermathecal canal caused by the muscular contraction of the wall. This duct always went through these peristalic movements when it was placed in the nutrient medium, but the oviducts, vasa deferentia, seminal vesicles, and other ducts never showed these movements.

Henneguy (1904) says that the spermatozoa which are deposited in the vagina are "emmagasinés" into the receptacle with great rapidity in one or two hours. Marchal (1894) thinks that the spermatozoa are sucked in by the contraction of the epithelio-muscular cylinder, which increases the capacity of the receptacle. Cappe de Ballion (1919) says that the mechanism of drawing in the spermatozoa by the spermatheca is a problem which has not received satisfactory solution. He states that since Marchal found striated muscles in the epithelial cells in the walls of the spermatheca of *Vespa germanica* that it may be sufficient explanation in the wasp, but it is not valid in some of the Orthoptera which belong to the Locustidæ which have spermathecas with rigid walls. He suggests that the presence of spermatozoa in an organ of this kind could only be explained by the movement characteristic of the spermatozoa.

After the spermatozoa have entered the spermatheca it is necessary for them to turn in the reservoir and come back down the long tube before fertilization. How and why do they pass back down the long tube?

The wall of both the spermatheca and the canal is lined with chitin, but the muscular contraction of the wall and the peristalic movements of the duct may aid in movement down the duct, but perhaps their own activity accounts for their return for fertilization. Noble and Weber (1929) found that in salamanders, although the spermatozoa had access to the oviducts and the large intestine, they were never found anterior to the opening of the spermathecal duct. They suggested that the spermatozoa entered the duct because of a chemotropic response to a secretion of the epithelial cells of the spermatheca. So it may be in *Gryllus* that the return of the spermatozoa down the tube is due to a chemotropic response to a secretion from the epithelial cells of the oviduct that is liberated at the time of oviposition.

VI. DESCRIPTION OF SPERMATOPHORE

The spermatophore is a receptacle for transferring the spermatozoa from the male to the female. It consists of a papilla, an ampulla, a neck, a plate, and a capillary tube which extends from the ampulla through the plate and 2 mm. beyond the plate. It is a white, yellow, or brown structure, depending upon how long it has been exposed, projecting from the posterior part of the ventral side of the adbomen of the female after copulation (Text Fig. 2). The size and shape of the spermatophores vary some, but ordinarily they are about 5.5 mm. from the posterior part of the papilla to the end of the capillary tube and are about 1.5 mm. wide in the widest part. The spermatophores vary in size according to the size of the spermatophore mold of the animals from which they are taken. There are some slight variations in size and shape, and shape

of parts of the spermatophores of different individuals, but the spermatophores of each individual are practically identical in size and shape.

The entire spermatophore is white when it is first formed, but after exposure the tube and the middle layer of the ampulla become brown or yellow, but the plate and papilla remain white. When the ampulla is filled with spermatozoa the center is white with a brown, hard wall around it (Fig. 55). but after the spermatozoa are forced out there is a white membrane extending from the posterior to anterior end of the vesicle (Figs. 58 and 59).

A small, white papilla protrudes from the posterior part of the ampulla (Figs. 55 and 57). The central part of this papilla is lined with the inner lining of the ampulla and has a few spermatozoa. This inner lining (Fig. 57, IM) passes through a small opening of the hard, apparently chitinous wall of the vesicle (Fig. 57 C) and enlarges in the ampulla; in other words, the inner lining forms a large bulbous pouch filled with the spermatozoa in the ampulla, narrows down into a narrow neck or canal and forms a smaller bulbous part in the papilla. Lespés (1855) noticed the extension of the central cavity of the ampulla back into the papilla. He says that this cavity ends by a large tube in the papilla. Boldyrev (1913, Text Fig. 11) evidently saw this membrane and spermatozoa in the papilla of the spermatophore of *Gryllus domesticus,* but did not interpret it as such. He does not recognize that there is a thin membrane lining the ampulla of the spermatophore.

The ampulla of the spermatophore is about 2 mm. long and 1.5 mm. wide. The wall consists of three parts (Fig. 59): (1) a thin, elastic, inner membrane which lines the cavity that is filled with spermatozoa and seminal fluid; (2) a thick middle layer of hard, apparently chitinous material, and (3) a thinner outer layer. The middle layer is 0.15 mm. thick and contains no vacuoles or granules. It takes a cytoplasmic stain, therefore must be formed from the secretion of the long, milky glands. The outer layer is thinner than the middle layer, being only 0.06 mm. The inner and outer layer look very much alike, except the inner layer is much thinner than the outer and both take a nuclear stain. Both must be formed from the secretion of the short glassy glands. The inner cavity is filled with spermatozoa, which have all their heads directed toward the tube, and seminal fluid. Jensen (1911), Boldyrev (1913), and others say that the ampulla has two layers—thick, hard, inner layer and an outer thinner layer. They failed to find the thin, inner membrane that lines the cavity and surrounds the spermatozoa.

The neck is a short tube between the ampulla and the plate. It is about 0.25 mm. long and is composed of the same layers as the ampulla. The lumen of the canal gradually tapers from the vesicle on to and through the plate.

The plate is a quadrilateral structure (Fig. 46) having two posterior lateral hooks and two anterior lateral hooks and one median anterior hook, with a tube passing through its center. These hooks are turned upwards in the female and are attached to the muscles around the ovipositor, thus holding the spermatophore firmly in the bursa copulatrix of the female. It is about 1 mm. long and 0.5 mm. wide in the center and wider at each end where the hooks are located. The plate is more or less flexible when it is removed from the male or female. When it is fully formed it has cross striations, which are visible in Fig. 46, but if the spermatophore is removed from the male soon after the plate is formed it will be very soft and show no striations (Fig. 60). The plate

has granules and vacuoles and takes a nuclear stain, thereby indicating that it is formed by the secretion from the short glassy glands. In fact, there is a continuation of the outer layer of the vesicle and neck on to the anterior end of the plate. This is very easily detected when the entire spermatophore is mounted in the nutrient medium and examined with low power. The dorsal side of the plate, or what is the ventral side in the female, seems harder and firmer than the ventral side, or what is the dorsal side in the female, and resembles the outer part of the outer layer of the vesicle while the ventral side resembles the softer inner part of the outer layer of the vesicle. The plate can be easily removed from the central canal (Fig. 48).

The capillary tube extends from the vesicle through the center of the plate and about 2 mm. beyond the plate. It gradually tapers from the vesicle to the end. It is lined with a very thin inner layer which is followed by a thick, apparently chitinous layer. That this is a capillary tube is evident from (Fig. 50). Lespés (1855, Fig. 2) thought the canal passed through the plate but that a horny thread extended beyond the plate.

When the spermatophores are removed from the females and placed in the nutrient medium the spermatozoa are forced out of the capillary tube like smoke out of a chimney (Fig. 48). Naturally, the question which Baumgartner (1910) suggested arises; namely, What forces the spermatozoa out of the spermatophore? Jensen (1911) says that he succeeded by "judicious pressure" to force the spermatozoa out of the spermatophore. Fulton (1931) suggests that pressure developed by the hardening and drying of the spermatophore will force the spermatozoa through the tube.

If the hardening and drying of the wall of the spermatophore develops a pressure that forces the spermatozoa out of the tube, why is it that the spermatozoa are not forced out into the spermatophore mold before they are transferred to the female when the male has separated from the female for several days and the spermatophore is exceedingly hard and brown?

In order to answer this question it was necessary to remove some fully formed spermatophores from males and see what happened. It is much more difficult to remove a spermatophore from a male than from a female, but it can be done by holding the male between the thumb and finger under the microscope and lowering the subgenital plate with a dissecting needle and carefully working the spermatophore back and forth until it comes loose.

Several attempts were made to remove the spermatophore from the male with the same results as those removed from the female, that is, the spermatozoa flowed out of the tube. Finally, a male was selected that had been separated from the female overnight and had a well-formed, hard, brown spermatophore. This was carefully removed from the male, placed in the nutrient medium, observed for several hours, and not a single spermatozoa flowed out of the tube. When the spermatophore was placed under the microscope a sharp point like the point of a needle which closed the end of the tube was clearly distinguishable (Figs. 51 and 52). It is impossible for the spermatozoa to flow out of the end of the tube until the point is dissolved or removed. Occasionally a spermatophore can be removed from a male that is copulating every hour without breaking off the sharp point. The spermatophore then, when it leaves the male, is a sealed ampulla. This prevents the loss of spermatozoa during the transfer from the male to the female.

When the spermatophores are removed from the females the point at the end of the capillary tube is never present though it is removed in a few seconds after copulation (Fig. 50). There must be some kind of enzymatic action that takes place rapidly in the bursa copulatrix of the female which dissolves the end of the tube and opens it. If a sealed spermatophore is placed on a slide and moved around with a dissecting needle the point is easily broken off, or sometimes only one side is broken loose, and the spermatozoa shoot out at one side.

When the end of the capillary tube is opened this relieves the pressure and the spermatozoa begin to flow out (Fig. 48). Then the inner elastic membrane begins to collapse at about the center of the ampulla, which is the widest diameter of the cavity (Fig. 56) and continues until it completely collapses (Figs. 58 and 59), forcing the spermatozoa out of the spermatophore. The outer layer of the wall of the ampulla must be permeable to air and permits its entrance around the papilla, thus preventing a vacuum. Then the air passes up between the inner membrane and the thick, hard wall and causes the complete collapse of the inner membrane.

The spermatozoa and seminal fluid are forced out in about 30 to 40 minutes if the spermatophore is removed from the female and placed in the nutrient medium, but it requires about 45 minutes to an hour for them to be forced out of the tube of the spermatophore into the bursa copulatrix of the female. This is probably due to the fact that there is more resistance to overcome when the spermatozoa are passed into the spermathecal canal than when they are liberated in the nutrient medium.

The removal of the spermatheca, spermathecal canal, and bursa copulatrix with the attached spermatophore is a very tedious and difficult task, since the bursa copulatrix is attached with numerous muscles and the tube of the spermatophore is easily pulled out of the bursa copulatrix. By carefully focusing and the proper light adjustment it is possible to trace the spermatozoa from the ampulla of the spermatophore up the long spermathecal canal into the spermatheca. After all of the spermatozoa have passed out the seminal fluid flows for five or ten minutes.

In one case the spermatophore was removed from a female after the male began stridulating. All of the spermatozoa had passed out, but the seminal fluid continued to flow for five minutes. It had been fifty-five minutes since copulation. The female attempted to remove the spermatophore and then copulated.

VII. FORMATION OF THE SPERMATOPHORE

Dahlgren and Kepner (1908) state that the walls of the sperm ducts of certain crustaceans secrete a fluid which forms a covering around the spermatozoa, which acts as a vehicle for carrying the spermatozoa. But in the cricket the spermatophore is formed by the secretions of the accessory glands. In this species there are two kinds of these glands: (1) the short, glassy glands (Fig. 31) which secrete the inner and outer layer of the wall, and (2) the long, milky glands (Fig. 32) which secrete the middle layer of the wall of the vesicle and the outer of the capillary tube.

In the squid the formation of the spermatophore is rapid; as many as 400 fully formed spermatophores may be found in the spermatophore sac of

one individual (Drew, 1919). In *Gryllus assimilis* as many as a dozen a day may be formed, but only one is found in an individual at one time, for there is room for only one spermatophore in the mold.

The spermatozoa pass out of the seminal vesicle into an enlarged portion or an ampulla (Fig. 33, AM) into which the accessory glands empty. While they are in this ampulla a secretion from the clear glands flows in and surrounds them. This usually happens within a few minutes after copulation. The spermatozoa, inclosed in this noncellular membrane, are forced down through the ejaculatory duct into the spermatophore mold by muscular contraction of the wall of the ejaculatory duct. Very seldom are these masses found in the ampulla or in the ejaculatory duct. They will probably be found in one case out of fifty dissections, due to the fact that they are forced out about as soon as the membrane is formed and the time for the formation of the membrane varies with different individuals. Lespés (1855) and Payne (1933) never found the spermatozoa in the ejaculatory duct. When this mass is found in the ejaculatory duct the membrane is transparent and soft and can be molded into any shape.

After the mass enters the spermatophore mold the pallets are forced out and hold the posterior end of the membrane while the secretion from the milky glands flows into the mold around the mass and forms the hard, middle layer of the vesicle and the outer layer of the capillary tube. Then a flow from the clear glands follows. This secretion forms the outer layer of the papilla, ampulla, and neck and the entire plate. When the spermatophore is fully formed most of the membrane and practically all of the spermatozoa have been drawn into the vesicle of the spermatophore. (Cf. Figs. 57 and 61). The capillary tube is formed in the tube of the mold (Figs. 39 and 41), but just how it is formed could not be determined.

In *Nemobius* the spermatophore is not formed until a short time before copulation (Fulton 1931), but in *Gryllus assimilis* the spermatophore is formed just after copulation, regardless of when they mate again.

The formation of the spermatophore is a very rapid process. In some instances the mass of spermatozoa, surrounded by the membrane, was found in the ampulla where the accessory glands empty within two minutes after copulation and in the ejaculatory duct within four minutes after copulation. The fully formed spermatophore, though very soft and white, may be found with the posterior part of the ampulla projecting from the subgenital plate within two minutes after copulation, but usually it is from five to ten minutes before it is fully formed. Copulation, undoubtedly, could not occur at this time because the plate and the tube are in a semiliquid condition.

VIII. COPULATION

The males and females were always kept separated except when observations were being made. Often the males began stridulating within five or ten minutes after they were put together, but sometimes it was thirty minutes or longer. On a few occasions when the female did not yield to the call of the male he killed and ate her, and in one case the female ate the male. Savin (1927) reports that two well-fed specimens of *Gryllus assimilis* kept in captivity chewed off and ate their own hind legs.

If the female fails to respond to the call of the male he will chirp at in-

tervals for hours. When this happens the male often reaches a shrill high pitch, but as the female approaches the pitch becomes softer. Lutz and Hicks (1930) say: "It seems fairly certain that crickets chirp by moving their wings in either direction, that each principal air wave is caused by the fanning of the wing as the tooth goes over the scraper, and that the pitch of the sound is a direct function of the number of teeth scraped per second. If this be true, it might be expected that different physiological and psychological states of the cricket would alter the pitch of the chirp" (p. 13).

The male usually stridulates five or ten minutes before the female pays any attention. While the male is making the sound with his wings he keeps his antennæ constantly in motion and moves toward the female. When he approaches the female, he lowers his abdomen and backs up in front of her. The female plays an active part in the process of copulation by responding to the call and mounting the male. The male often sings for some time before the female makes a move; then she begins removing the spermatophore; she bends her abdomen ventrally, catches the ovipositor with her middle tarsus, and removes the spermatophore with her mouth parts. This is the method she usually uses to rid herself of the spermatophore, but occasionally she rubs it off by dragging the abdomen on the bottom of the jar. In a few cases she tried but failed to remove it and mounted the male with it still in position. After some efforts the male succeeded in removing it by some backward and forward movements of the abdomen and then placed a new spermatophore in its place. Sometimes the female eats the spermatophore and sometimes she drops it after she removes it.

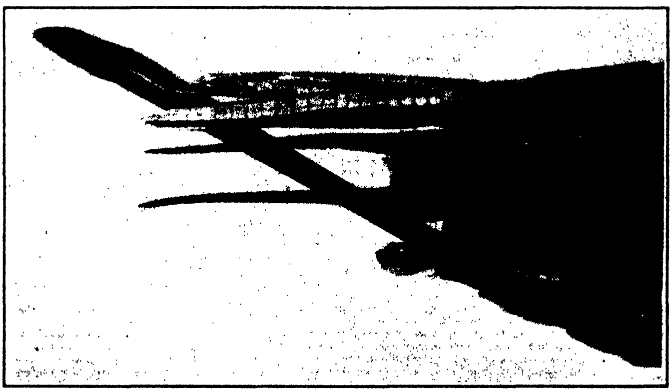
Lespés (1855) says that the female carries the spermatophore for some hours in the vagina and that it seems that she makes no effort to remove it but that it falls. Boldyrev (1913) states that after the females have carried the spermatophores for an hour or more that they fall out by the contraction of the abdomen without the use of the mouth parts. He also says that when the female *Gryllus* is scared she will bite off the spermatophore while it is still filled with spermatozoa. These observations were not confirmed.

Hancock (1905), Houghton (1909), Turner (1916), Gerhardt (1921), and others seem to think that the female has to be entertained by the male some way or other to prevent her from eating the spermatophore. This is not true of *Gryllus assimilis*. As soon as copulation was completed the male glided from under the female and paid her no more attention until the time arrived for copulation again. While they were under observation the females made no attempt to remove or eat the spermatophores until the male began stridulating. Numerous cases were tried in which the spermatophores were removed from the females just after, just before, and at different intervals between copulation, and in every instance the female went through the performance of removing the spermatophore just as though it were present. It seems to be an instinct for the females to remove the spermatophore after the male begins stridulating.

After the female mounts the male, the male raises his abdomen and fastens the three brown hooks in the opening between the ovipositor and the subgenital plate, thus lowering the plate. This holds the two bodies firmly together. The spermatophore is forced out of the spermatophore mold by muscular contraction and is held by the two pallets which are located on each

side of the mold. Then the male raises the abdomen and with some backward and forward movements of the abdomen succeeds in placing the capillary tube of the spermatophore into the small opening of the bursa copulatrix (Figs. 62 and 63). The entire tube of the spermatophore is inserted up into the tube of the bursa copulatrix to the plate of the spermatophore.

The spermatophore, when it is in the mold, is so bent that the ampulla and the tube almost meet; therefore, when the male removes the spermatophore from the mold the tube and plate open through an angle of almost 180 degrees. Instead of opening back like the leaves of a book it rolls out just as though you placed the two edges of a sheet of paper almost together and pulled the lower edge. What was the dorsal side of the plate of the spermatophore in the male becomes the ventral side in the female by being straightened out before it is placed in the female; therefore the hooks that



TEXT FIG. 2. Posterior part of the abdomen of a female *Gryllus assimilis* with the spermatophore. X 5.

pointed downward or ventrally in the male point upward or dorsally in the female. The spermatophore is placed between the ovipositor and the subgenital plate with the capillary tube in the bursa copulatrix and left in this position with the ampulla projecting (Text Fig. 2). The hooks of the spermatophore are fastened to the muscles around the ovipositor.

Just after copulation the spermatophore has a white opaque mass in the center of the ampulla, but this mass gradually diminishes in size as the spermatozoa and seminal fluid are forced into the spermatheca and the spermatophore becomes translucent in appearance. Gillette (1904, p. 324) states that "after 2 or 3 hours these masses disappear entirely, but whether the contents are largely taken in by the female or whether she rejects the greater portion after extracting the spermatozoa, I did not determine." He seems to think that the female extracts the spermatozoa from the spermatophore. In the case of *Gryllus assimilis* the spermatozoa are forced out of the spermatophore regardless of whether the tube enters the bursa copulatrix of the female or not; if the spermatophore is removed from the female and placed in the nutrient medium the spermatozoa are forced out just the same.

The act of copulation lasts about thirty seconds, but occasionally the male

fails to place the tube of the spermatophore in the bursa copulatrix and the female dismounts. Then the male begins stridulating again and the female remounts. As soon as copulation is completed the female dismounts or the male slips from under the female. Fulton (1931) says that in *Nemobius* the female stays mounted from 15 to 25 minutes and bites on a spine on the hind tibia, which is an alluring gland.

In one case, after the male began stridulating he was caught and the spermatophore removed, and in ten minutes he was chirping again. The female mounted and they went through the process of copulation, but no spermatophore was formed or given to the female. An hour later they copulated normally.

Imms (1925) says that in most insects copulation takes place only once. Gillette (1904) says that he was unable to determine whether copulation took place more than once in *Anabrus*. Boldyrev (1913) states that the Gryllidæ copulate several times daily.

Data were taken on 50 pairs and they copulated about every hour when kept in captivity. Table I gives a record of two pairs. If they are placed together early in the morning and left together until late in the afternoon they will copulate ten or eleven times. If the same pair is kept together during the day and separated during the night they will continue this rate of copulation for several days.

A record was kept of one pair of crickets that was collected in the nymph stages and kept separated until maturity, then they were placed together during the day and separated during the night. This pair mated forty times in four days. The male died during the night and the female was placed with another male. She continued to copulate with the new male. The male that died was dissected and a completely formed, hard, brown spermatophore was found in the mold. The testes were not exhausted; in fact, it could hardly be noticed that any spermatozoa had been removed from the testes during the four preceding days.

There must be thousands of spermatozoa placed in the spermatophore When a spermatophore is removed from the female just after copulation and placed in the nutrient medium thousands of spermatozoa are liberated.

TABLE I.—COPULATION

ber.	Date.	Hour.	Time for Copulation.
	July 4, 1932	8:55	28 sec.
	July 4, 1932	9:40	30 sec.
	July 4, 1932	10:22	29 sec.
	July 4, 1932	11:08	30 sec.
	July 4, 1932	12:00	24 sec.
	July 4, 1932	1:00	30 sec.
	July 4, 1932	2:00	31 sec.
	July 4, 1932	3:00	29 sec.
	July 4, 1932	3:57	30 sec.
	July 4, 1932	4:57	30 sec.
	July 4, 1932	5:00	31 sec.
	June 9, 1933	7:40	31 sec.
	June 9, 1933	8:30	30 sec.
	June 9, 1933	9:30	29 sec.
	June 9, 1933	10:18	30 sec.
	June 9, 1933	11:10	25 sec.
	June 9, 1933	12:00	30 sec.

Number.	Date.	Hour.	Time for Copulation.
	June 9, 1933	12:53	31 sec.
	June 9, 1933	1:45	30 sec.
	June 9, 1933	2.43	29 sec.
	June 9, 1933	3:40	30 sec.
	June 9, 1933	4:40	29 sec.
2	June 10, 1933	8:30	28 sec.
	June 10, 1933	9:20	30 sec.
	June 10, 1933	10:08	29 sec.
	June 10, 1933	11:00	27 sec.
	June 10, 1933	11:45	31 sec.
	June 10, 1933	12:45	30 sec.
	June 10, 1933	1:37	30 sec.
	June 10, 1933	2:28	25 sec.
	June 10, 1933	3:15	32 sec.
	June 10, 1933	4:24	30 sec.

IX. SUMMARY

1. The reproductive systems of *Gryllus* are more complicated than was commonly reported by the earlier investigators.

2. The bursa copulatrix of *Gryllus assimilis* is not formed by a diverticulum of the vagina but is formed by an ectodermal invagination; therefore, there are two openings of the female reproductive system, the opening of the bursa copulatrix and the opening of the vagina. Both of these open into a common chamber which is called by Snodgrass (1933) the genital chamber. The egg must be fertilized just before oviposition as it is pushed past the opening of the bursa copulatrix.

3. The reproductive system of the male nymph is very simple, consisting of a pair of testes, vasa deferentia, and a terminal ampulla or pouch without an external opening, as compared with the reproductive system of an adult which consists of a pair of testes, vasa deferentia, seminal vesicles, an ampulla or pouch into which the accessory glands empty, the ejaculatory duct with its accessory pouches, the spermatophore mold, and two lateral pallets. The accessory glands are formed as diverticula of the terminal ampulla and are mesodermal in origin. The seminal vesicles are modifications of the vasa deferentia, therefore are mesodermal. The ejaculatory duct and its accessary pouches and the spermatophore mold are formed by an ectodermal invagination that meets and fuses with the terminal ampulla.

4. There are two kinds of accessory glands: (1) long, milky glands that secrete the middle layer of the vesicle of the spermatophore and the outer layer of the capillary tube, and (2) short, glassy glands whose secretion forms the inner and the outer layer of the vesicle and the entire plate.

5. The spermatozoa have been followed from the follicles of the testes of the male to the genital opening of the female by means of the intravitam technique. The spermatozoa of the proximal cyst of the follicle turn within the cyst, but the spermatozoa of the remainder of the cysts break out of the cyst, spiral up the follicle, turn in the spermatid region, and spiral back down the follicle; they travel in pseudo-aggregations, but are not fastened together by a cytoplasmic cap. They pass down the vas deferens and are stored in the convoluted seminal vesicles. In the ampulla into which the accessory glands and seminal vesicles empty they are surrounded by a membrane and are forced down the ejaculatory duct by muscular contraction into the spermatophore mold where the spermatophore is formed. Then after copulation they

are forced into the bursa copulatrix from the spermatophore. They pass up the spermathecal canal into the spermatheca, where they are stored until fertilization.

6. The spermatophore consists of: (1) a papilla; (2) a vesicle which has a wall of three noncellular layers, a thin, inner membrane lining the cavity which is filled with spermatozoa and seminal fluid, a middle thick, apparently chitinous, layer and a thinner outer layer; (3) a neck; (4) a plate which has five hooks for attachment in the female; and (5) a capillary tube, which is placed into the bursa copulatrix of the female during copulation, through which the spermatozoa exit.

7. The wall of the spermatophore is formed from secretions of the accessory glands. The spermatozoa are surrounded by the secretion of the glassy glands in the pouch into which they empty, and this mass is forced down the ejaculatory duct into the spermatophore mold. The posterior part of the mass is held by the pallets while the secretion of the milky glands flows in and forms the middle layer. Then there is another flow from the glassy glands which forms the outer layer and the plate. The entire spermatophore is formed in a few minutes after copulation.

8. The spermatozoa and seminal fluids are forced out of the spermatophore. The spermatophore is a sealed ampulla when it leaves the male. There must be an enzymatic action which takes place readily in the bursa copulatrix and dissolves the needlelike point of the capillary tube. This relieves the pressure and the spermatozoa begin to flow out of the tube. Air must enter through the outer layer around the papilla and passes between the inner and middle layer, thus causing the collapse of the elastic inner membrane which forces the spermatozoa and seminal fluid out of the spermatophore. All the spermatozoa and seminal fluid are forced out in about 45 minutes or an hour.

9. The female mounts the male, and he places the capillary tube of the spermatophore into the bursa copulatrix. The act of copulation lasts about 30 seconds, and then the two sexes separate immediately. They copulate about every hour. They will copulate ten or twelve times daily and will continue this rate of copulation for several days.

The writer wishes to express her appreciation to Dr. W. J. Baumgartner, under whose direction this investigation was made, for his personal interest and assistance, and to Dr. H. H. Lane for his helpful suggestions.

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EXPLANATION OF PLATES

All the pictures are photomicrographs of living material except photos 40, 49, and 54. Photos 40 and 54 were fixed in Bouin's fixative and stained in Delafield's hematoxylin and eosin, and 49 was fixed in 95 per cent alcohol and unstained. The photographs were made with an arc illuminant on negative print paper. The tissues were removed from the insect, mounted in nutrient medium, and immediately photographed.

ABBREVIATIONS USED ON THE PLATES

A, accessory pouch.
AM, ampulla or pouch of adult into which the accessory glands and seminal vesicles empty.
B, bursa copulatrix.
C, canal of the middle layer of the spermatophore through which the inner membrane extends.
E, ejaculatory duct.
G, accessory glands.
H, hooks male uses in clasping the female during copulation.
I, inner membrane of the spermatophore.
IM, inner membrane of the spermatophore extending into the papilla.
K, place of muscle attachment.
M, middle layer of spermatophore.
O, outer layer of spermatophore.
OV, oviduct.
P, pouch of a nymph from which the accessory glands develop.
PL, pallets.
S, ampulla of the spermatophore.
SM, spermatophore mold.
SP, spermatheca.
SV, seminal vesicle.
T, testis.
V, vagina.
VD, vas deferens.

PLATE XIII

FEMALE REPRODUCTIVE SYSTEM

EXPLANATION OF FIGURES

FIG. 1. Nymphal stage of the spermatheca taken from a nymph (body length 12 mm.). $\times$ 75.

FIG. 2. A later stage of the spermatheca taken from a nymph (body length 15 mm.). Note that a lumen has been formed in this stage. $\times$ 75.

FIG. 3. Magnified view of the bursa copulatrix of figure 6. Note that the spermathecal canal does not extend to the end of the bursa copulatrix. $\times$ 35.

FIG. 4. Magnified view of the spermathecal canal with attached tracheæ of figure 6. $\times$ 75.

FIG. 5. Magnified view of the spermatheca of figure 6. Many tracheæ visible. $\times$ 36.

FIG. 6. Bursa copulatrix, spermathecal canal, and spermatheca of a nymph (body length 17 mm.). $\times$ 12.

FIG. 7. Bursa copulatrix, spermathecal canal, and spermatheca of an adult. The connective tissue has been removed and the convoluted canal extended. $\times$ 10.

FIG. 8. Bursa copulatrix of an adult with the muscles and connective tissue removed. $\times$ 30.

FIG. 9. Ventral view of the oviducts, vagina, and spermatheca of an adult. The bursa copulatrix has been pulled from under the vagina so that it will show in the photograph. $\times$ 12.

PLATE XIII

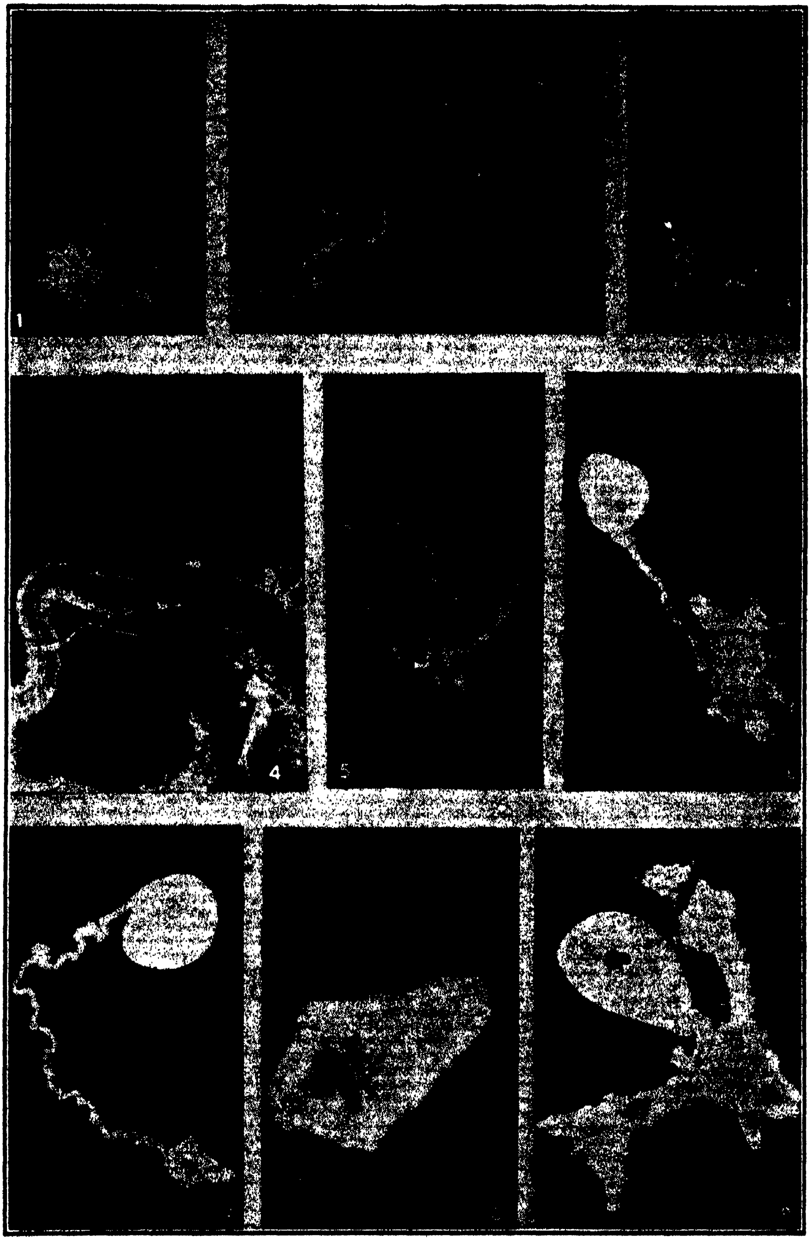


PLATE XIV

FEMALE REPRODUCTIVE SYSTEM

EXPLANATION OF FIGURES

FIG. 10. Ovaries and oviducts from a nymph (body length 11 mm.). × 10.

FIG. 11. Ovaries, oviducts, and vagina of a nymph (body length 17 mm.). Note the shortening and thickening of the oviducts as the nymph matures. × 10.

FIG. 12. Ovarian tubules showing the terminal filament, germarium, and vitellarium. Note the developing eggs. × 75.

FIG. 13. Ovary of a nymph (body length 11 mm.) with the ovarian ligament and oviduct attached. × 30.

FIG. 14. Ovary of a nymph (body length 10 mm.) with the connective tissue removed showing the ovarian tubules. × 12.

FIG. 15. Mature egg. × 12.

FIG. 16. Ovarian tubules attached to the oviduct with part of the connective tissues and tracheæ removed. × 35.

FIG. 17. Ovarian tubules showing the attachment to the oviduct. × 75.

FIG. 18. Magnified view of the germarium and part of the terminal filament. Note the developing egg cells. × 290.

PLATE XIV

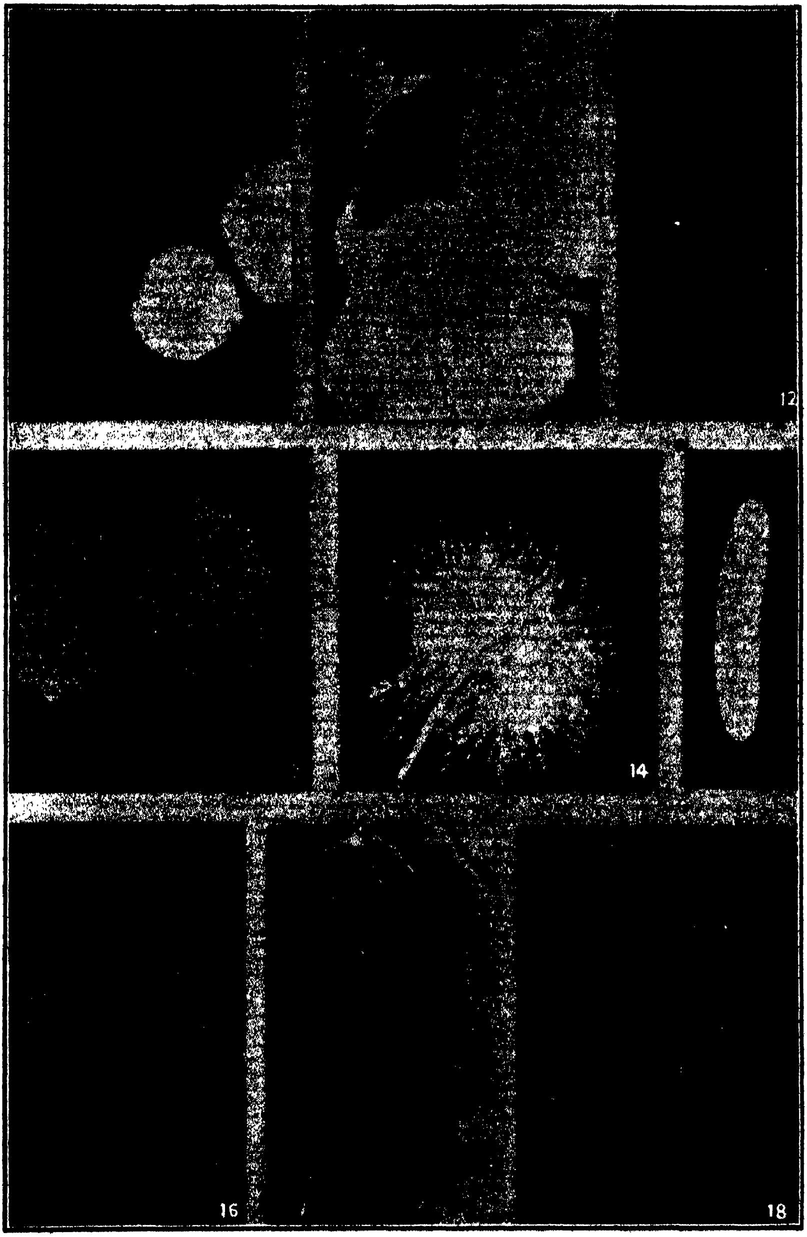


PLATE XV

MALE REPRODUCTIVE SYSTEM

EXPLANATION OF FIGURES

FIG. 19. Male reproductive system of a nymph (body length 12 mm.). At this stage the reproductive system is composed of the testes, vasa deferentia, and a pouch from which the accessory glands are formed. × 12.

FIG. 20. Later stage of the male reproductive system of a nymph (body length 18 mm.). Note the increase in size and changed shape of the pouch. × 12.

FIG. 21. Lateral view of part of the accessory glands, ejaculatory duct, spermatophore mold with the ampulla of the spermatophore projecting, and the hooks, which the male attaches to the female during copulation, of an adult. × 12.

FIG. 22. Magnified view of the pouch of fig. 19. × 35.

FIG. 23. Magnified view of a pouch of a nymph (body length 18 mm.). Numerous tracheæ visible. × 30.

FIG. 24. Testis and vas deferens of a nymph (body length 10 mm.). The connective tissue is ruptured and some of the follicles are projecting. × 10.

FIG. 25. Vas deferens with the attached follicles removed from the posterior end of the testis. Note the spermatozoa in the follicles. × 35.

FIG. 26. Portion of the vas deferens near the seminal vesicle, with a bundle of spermatozoa traveling from the testis to the seminal vesicle. × 35.

FIG. 27. Portion of the seminal vesicle filled with spermatozoa. The wall is ruptured and the spermatozoa are escaping. × 30.

PLATE XV

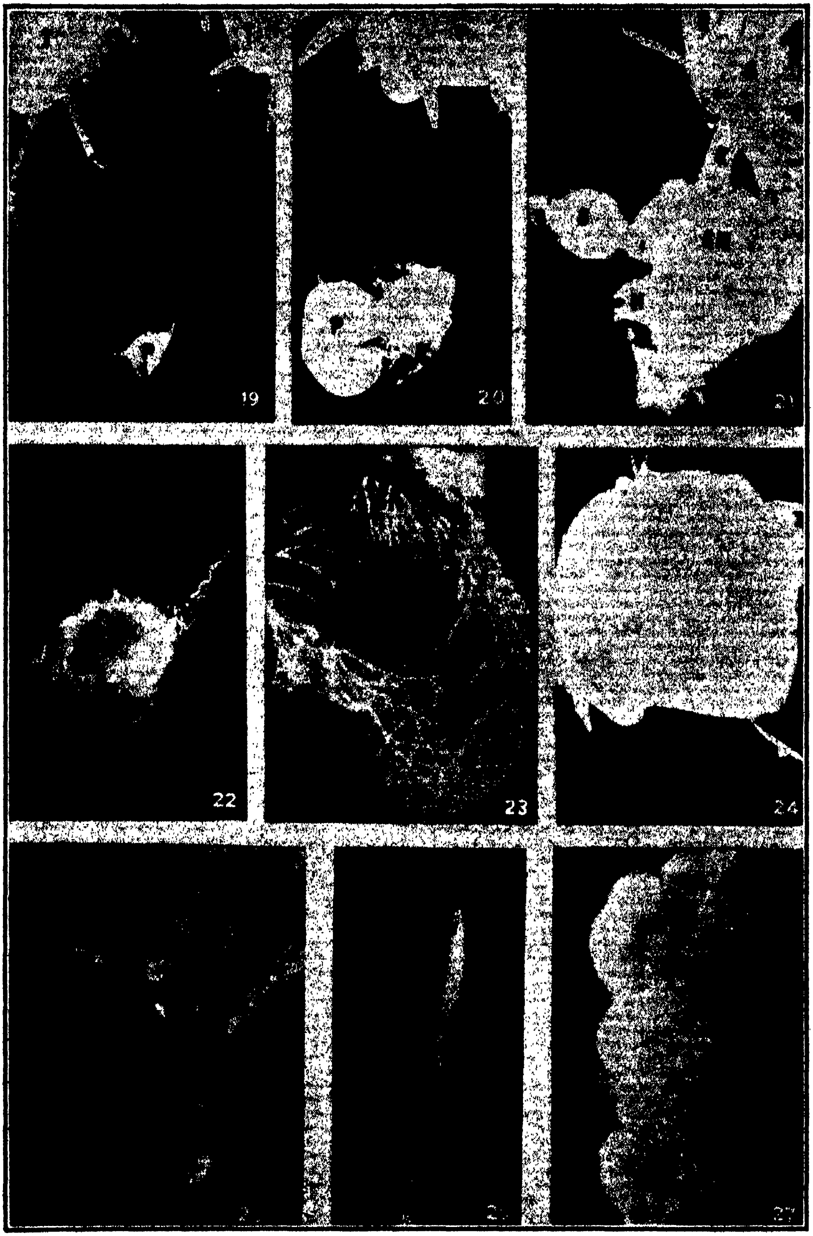


PLATE XVI

MALE REPRODUCTIVE SYSTEM

EXPLANATION OF FIGURES

FIG. 28. Part of the accessory glands. × 12.

FIG. 29. Vas deferens, seminal vesicle, accessory glands, ejaculatory duct and accessory pouches. × 8.

FIG. 30. Magnified view of the ejaculatory duct and two accessory pouches of fig. 29. × 35.

FIG. 31. Portion of the clear accessory glands. × 75.

FIG. 32. Part of two milky accessory glands. × 75.

FIG. 33. Seminal vesicles entering the enlarged ampulla. Most of the accessory glands have been removed. × 12.

FIG. 34. Seminal vesicles entering the enlarged ampulla. Part of the accessory glands are attached. × 10.

FIG. 35. Posterior part of the vas deferens and the anterior part of the seminal vesicle. × 75.

FIG. 36. Posterior part of the seminal vesicle. × 75.

PLATE XVI

PLATE XVII

MALE REPRODUCTIVE SYSTEM

EXPLANATION OF FIGURES

FIG. 37. Lateral view of the spermatophore mold. $\times 12$.

FIG. 38. Magnified view of fig. 37. Note the point where the canal of the spermatophore is formed. $\times 20$.

FIG. 39. Lateral view of the spermatophore mold with the tissues removed to show the posterior hooks. $\times 20$.

FIG. 40. Cross section of the spermatophore mold where the posterior hooks of the plate are formed. (Bouin's fixative, Delafield's hematoxylin, and eosin.) $\times 75$.

FIG. 41. Magnified view of the point of the spermatophore mold where the canal of the spermatophore is formed. $\times 75$.

FIG. 42. Spermatophore mold with the pallets which hold the ampulla of the spermatophore after it is forced out of the mold, and the hooks which are attached to the female during copulation. $\times 12$.

FIG. 43. Magnified view of the pallets. $\times 35$.

FIG. 44. Magnified dorsal view of the hooks. $\times 35$.

FIG. 45. Magnified lateral view of the hooks. $\times 75$.

PLATE XVII

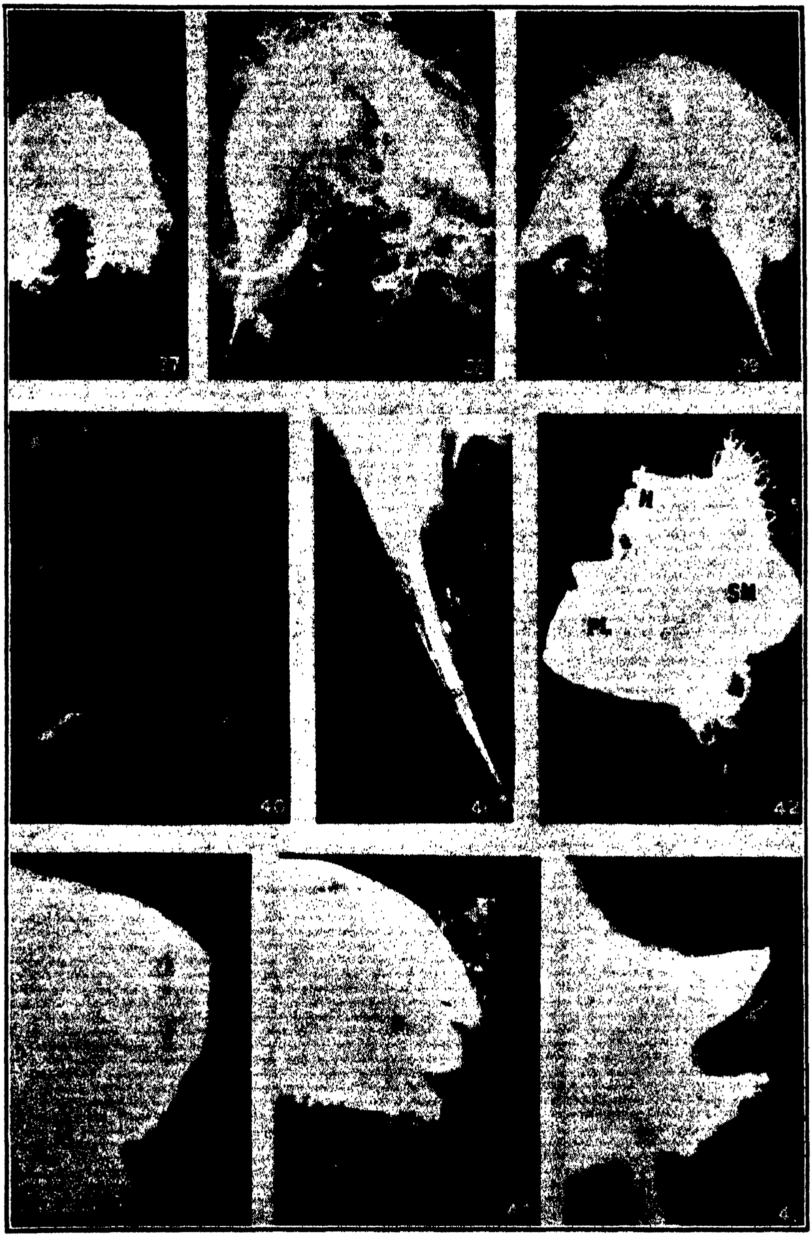


PLATE XVIII

SPERMATOPHORE

EXPLANATION OF FIGURES

FIG. 46. Ventral view of a spermatophore removed from a female. Note the plate with the canal passing through the center and the hooks. × 12.

FIG. 47. Dorso-lateral view of a spermatophore removed from a female. Part of the canal is bent back under the plate. × 15.

FIG. 48. Spermatophore with the plate dissected away, removed from a female just after copulation. The spermatozoa at the end of the canal were forced out of the ampulla through the canal into the nutrient medium. Note carefully the capillary tube extending from the ampulla to the mass of spermatozoa. × 12.

FIG. 49. The mass of spermatozoa surrounded by the inner layer of the spermatophore from the ampulla of the spermatophore. The middle chitinous layer and the outer layer have been removed. (Fixed in 95 per cent alcohol.) × 35.

FIG. 50. Free end of the canal of a spermatophore removed from a female. × 290.

FIG. 51. Free end of the canal of a spermatophore removed from a male. Note the sharp point at the end and compare with figure 50. × 75.

FIG. 52. Magnified view of figure 51. The point is not in sharp focus. Note that the canal is closed at the end. × 300.

FIG. 53. Magnified view of the canal at the attached end with the plate removed. × 290.

FIG. 54. Cross section of the spermatophore plate showing the canal. (Bouin's fixative, Delafield's hermatoxylin, and eosin.) × 75.

PLATE XVIII

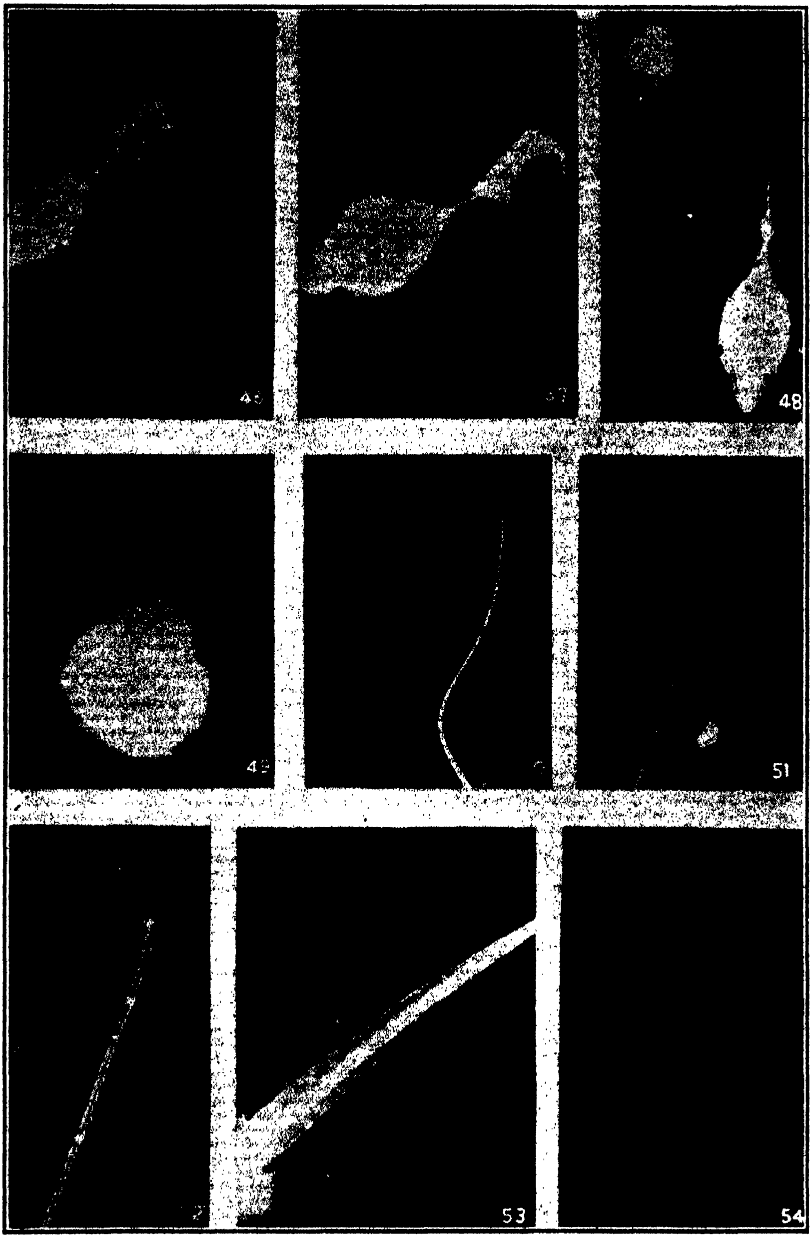


PLATE XIX

SPERMATOPHORE

EXPLANATION OF FIGURES

FIG. 55. Ampulla of a spermatophore removed from a female immediately after copulation and filled with spermatozoa. × 35.

FIG. 56. Ampulla of a spermatophore removed from a female 5 minutes after copulation. The spermatozoa have been passing out of the vesicle and the inner wall is beginning to collapse. × 38.

FIG. 57. Posterior end or papilla of the spermatophore. × 75.

FIG. 58. Anterior part of the ampulla of a spermatophore removed from a female 45 minutes after copulation. The inner wall of the vesicle is collapsed. × 45.

FIG. 59. Posterior part of the same spermatophore as figure 58. × 45.

FIG. 60. Plate of a spermatophore removed from a male 20 minutes after copulation. × 35.

FIG. 61. Papilla of a spermatophore removed from a male 5 minutes after copulation. × 75.

FIG. 62. The spermatheca and bursa copulatrix with the attached spermatophore of the male removed from the female just after copulation. The canal of the spermatophore in its normal position after copulation is inserted up to the plate into the bursa copulatrix but during the dissection it was partly removed. × 8.

FIG. 63. Magnified view of figure 62. Note the canal of the spermatophore enters the bursa copulatrix some distance from the end. × 12.

PLATE XIX

PLATE XX

FOLLICLES OF THE TESTIS

EXPLANATION OF FIGURES

FIG. 64. Proximal end of three follicles showing the cysts extending across the entire follicle filled with spermatogonial cells. Note the cells and the milky secretion in the middle follicle. × 75.

FIG. 65. Portion of a follicle that is more mature, the upper cyst containing spermatocytes and the lower one early spermatids. × 75.

FIG. 66. Portion of a follicle with the middle cyst full of spermatids of which the forming heads are taking a peripheral position. × 75.

FIG. 67. Open end of a follicle showing the spermatids turning in the cyst. × 75.

FIG. 68. Open end of a follicle showing the first cyst elongated and the spermatids with their heads toward the open end of the follicle, and the second cyst pulled loose from the follicle wall and the spermatid heads taking a peripheral position. × 75.

FIG. 69. Blind end of follicle showing the cysts in different stages of development. × 75.

FIG. 70. Portion of a follicle showing one cyst of spermatids pulling loose from the follicle wall and another cyst of spermatids with all their heads directed toward the blind end of the follicle. × 75.

FIG. 71. A more mature follicle than photo 70, with one cyst of spermatids collecting with their heads toward the blind end of the follicle and two other masses of spermatids ready to move up the follicle. × 75.

FIG. 72. A still more mature follicle with one cyst of spermatids pulled loose from the follicle wall and a mass of spermatids pushing up between the cyst and the wall. × 75.

PLATE XX

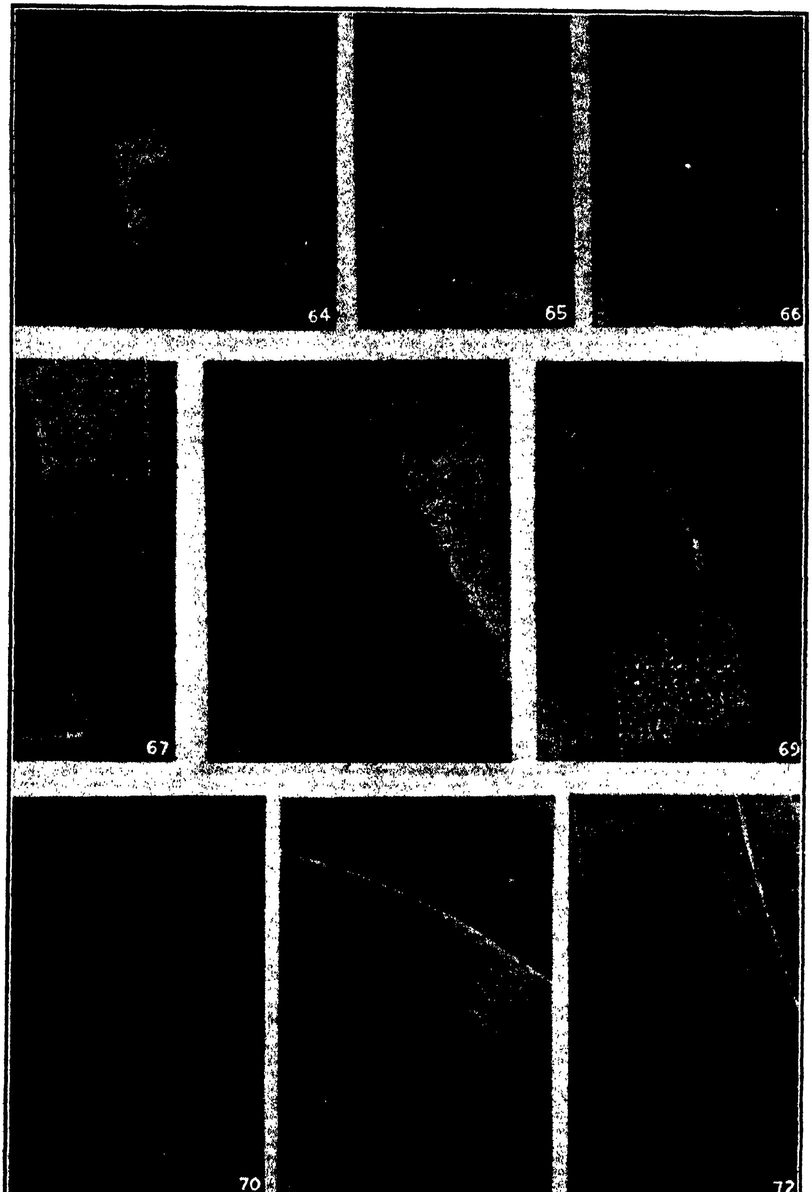


PLATE XXI

FOLLICLES OF THE TESTIS

EXPLANATION OF FIGURES

FIG. 73. Portion of a follicle with two masses of spermatids in focus beneath the cysts of spermatids. × 75.

FIG. 74. Portion of a follicle with all of the cyst walls broken down and three bundles of spermatozoa traveling up the follicle beside each other. × 75.

FIG. 75. Three bundles of spermatozoa traveling up the follicle, one advancing in front of the other. × 75.

FIG. 76. Proximal portion of three follicles with all of the cyst walls broken down. × 35.

FIG. 77. Proximal portion of two follicles with a bundle of spermatozoa pasing out of a follicle into the duct which leads into the vas deferens. × 75.

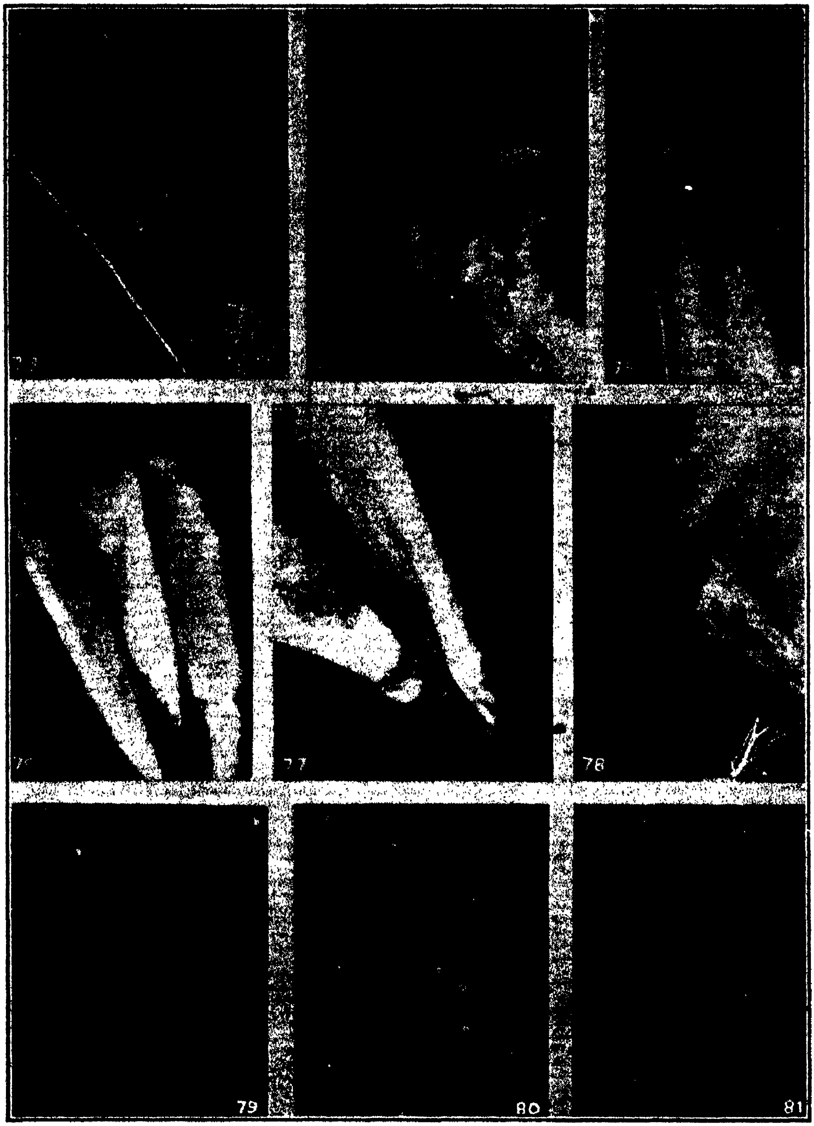
FIG. 78. Portion of a follicle with a ruptured wall and the spermatids escaping. × 75.

FIG. 79. Magnified view of spermatids with blebs along the tails from figure 78. × 290.

FIG. 80. Spermatids with round heads that have flowed out of ruptured follicle. × 290.

FIG. 81. Mature spermatozoa that have been forced from the spermatheca of the female into the medium. × 290.

PLATE XXI



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